A DISSERTATION ON

"TO STUDY THE RELATIONSHIP OF APPARENT DIFFUSION COEFFICIENT (ADC) VALUES OF RENAL PARENCHYMA AND RENAL RESISTIVE INDEX (RRI) WITH SERUM MARKERS OF RENAL DYSFUNCTION AND STAGE OF CHRONIC KIDNEY DISEASE''

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BONAFIDE CERTIFICATE

Certified that this dissertation is the bonafide work of Dr.K.SIVAKUMAR on **"TO STUDY THE RELATIONSHIP OF APPARENT DIFFUSION COEFFICIENT (ADC) VALUES OF RENAL PARENCHYMA AND RENAL RESISTIVE INDEX (RRI) WITH SERUM MARKERS OF RENAL DYSFUNCTION AND STAGE OF CHRONIC KIDNEY DISEASE"** during his **M.D. RADIODIAGNOSIS** course from May 2012 to April 2015 at the Madras Medical College and Rajiv Gandhi Government General Hospital, Chennai – 600003.

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DECLARATION

I, **Dr.SIVAKUMAR K** solemnly declare that dissertation titled **"TO STUDY THE RELATIONSHIP OF APPARENT DIFFUSION COEFFICIENT(ADC) VALUES OF RENAL PARENCHYMA AND RENAL RESISTIVE INDEX(RRI) WITH SERUM MARKERS OF RENAL DYSFUNCTION AND STAGE OF CHRONIC KIDNEY DISEASE"** is a bonafide work done by me at Madras Medical College and Rajiv Gandhi Government General Hospital, Chennai-3 under the guidance of my HOD **Prof. N.KAILASANATHAN DMRD, M.D.** Professor of Radio-diagnosis & under the supervision of **Prof. K. VANITHA, DMRD, DRM, MD ,** Director, Barnard Institute of radiology Madras Medical College and Rajiv Gandhi Government General Hospital, Chennai.

This dissertation is submitted to Tamil Nadu Dr. M.G.R Medical University, towardspartial fulfillment of requirement for the award of **M.D. Degree (Branch – VIII) in RADIODIGNOSIS– APRIL-2015.**

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CONTENTS

ABSTRACT

BACKGROUND:

Diffusion-weighted magnetic resonance imaging (DW-MRI) in renal diseases is an emerging field and its utility is yet to be fully realized.

AIM: To study the relationship between apparent diffusion coefficient (ADC) values of renal parenchyma, Renal Resistive Index (RI) with serum markers of renal function and stage of chronic kidney disease (CKD).

Materials and Methods: A prospective study was performed 100 patients with normal and elevated renal parameters .Patients underwent DW-MRI (at b-values of 0, 250 and 500 s/mm^2) and renal Doppler examination.

Of these 25 normal GFR, 26 patient's stage2, 20patients stage3, 10 patients stage4, 19 patients stage 5 CKD and were staged depending on disease severity.

ADC values were determined for renal parenchyma and compared. Receiver operating characteristic (ROC) curves were drawn to establish cut-off ADC values. Pearson's correlation coefficient (R) was calculated between ADC and renal function parameters.

Results: ADC values in patients with renal dysfunction were significantly lower than in patients with normal renal function .

ADC values lower than 1.986 x$10^{-3}$$mm^{2/sec}$ for right side ,1.97067 x$10^{-3}$$mm^{2/sec}$ for left side were seen only with renal dysfunction and higher than 2.49318 ($\times 10^{-3}$ mm^2/s) for right side 2.4706for left side , were seen only with normal function. Average ADC value for both side: 2.334 X $10^{-3}$$mm^2$/sec below which indicates renal dysfunction.

There was significant inverse correlation between ADC of renal parenchyma and serum creatinine, blood urea . There is significant linear correlation between the ADC of renal parenchyma and estimated glomerular filtration rate (eGFR).

ADC values showed a statistically significant decreasing trend with increasing stage of CKD.

Renal resistive index is not persistently elevation in all the patients with elevated renal parameters and couldn't be reliable in predicting the renal dysfunction.

Conclusion: ADC values may serve as an additional marker for the presence and degree of renal dysfunction

KEY WORDS:

ADC	:	Apparent diffusion co efficient value ,
ARF	:	Acute renal failure,
AoCRF	:	Acute on chronic kidney disease,
CKD	:	Chronic kidney disease
DWI	:	Diffusion weighted imaging,
GFR	:	Glomerular filtration rate,
MRI	:	Magnetic resonance imaging
RI	:	Resistive index,
PSV	:	Peak systolic velocity,
EDV	:	End diastolic velocity

INTRODUCTION

Background:

Chronic renal disease is a world-wide health problem with the overall incidence of the end-stage renal disease is 100-150 /million populations[1].

Renal dysfunction: Is a Condition defined according to the presence or absence of damage of the kidneys and level of kidney function, not related to the type of kidney damage.

Many people having reduced renal function have a renal disorder which will worsen over course of time.

Various health problems manifest when the kidney function falls lesser than 25%. When glomerular filtration (GFR) falls under 15%, people can't live long without renal replacement therapy like either with dialysis or transplantation.

Renal function:

Renal function is assessed by means of effective glomerular filtration rate (e-GFR).

GFR is defined as how many millilitres of blood in the kidneys are able to filter within one minute.

The normal value of GFR is 90 ml/min or higher.

GFR is expressed in terms of body surface area, which averages $1.73/m^2$.

If the GFR is too low, kidney becomes unable to remove enough creatinine and extra water from the blood.

GFR can be measured indirectly from the estimation of creatinine in the blood. Creatinine is derived from the breakdown of normal muscle cells. So the amount of serum creatinine correlates with level of kidney function.[2]

Renal dysfunction is determined either absence / decrease in the production of urine or elevation in the waste products (serum Creatinine / blood Urea) level in the blood.

RENAL DYSFUNCTION TYPES:

1. ACUTE 2.CHRONIC

It can be differentiated by the level of the serum creatinine and blood urea.

In persons with chronic renal failure, the stages of the chronic kidney disease (CKD) is defined based on the functioning level of the kidneys.

Definition and Classification:

Renal failure defined as a condition in which defect in the filtration and excretion of the waste products from the body by the kidneys.

The two types of kidney injury are Acute and Chronic based on the duration of dysfunction of kidneys.

Acute renal failure is a reversible condition with adequate treatment however the chronic kidney disease (CKD) is usually irreversible despite of treatment.

Acute Renal failure: (ARF)

Rapid deterioration of renal function with progressive azotaemia (raised serum creatinine) may or may not be associated with oliguria.

Factors which aids to differentiate acute from the chronic kidney disease include anaemia and the kidney size, because in chronic kidney disease(CKD) usually there will be reduced kidney size (8cm).

Chronic kidney disease -CKD:

CKD is defined as persistent kidney injury greater than 3 months duration results in the reduction of GFR less than 60 ml/min/1.73m^2.

Slow progressive loss of renal dysfunction occurs over a long span of duration, leads to kidney damage permanently.

CKD can be secondary to acute renal disease due to progression of ARF.

Acute-on-chronic kidney Disease:

Acute kidney injuries (AKI) can manifest as be initial stage of CKD and the condition is known as acute-on-chronic renal failure (AoCRF).

AoCRF may be reversible if it is treated initially and its severity is measured by serum creatinine.

It will be difficult to differentiate chronic renal failure (CRF) from AKI and from AoCRF, so the patient should be monitored regularly and baseline parameters should be available for comparison.

Causes of kidney injury:

Acute kidney injury:

Pre-renal:

- Hypovolemia
- Shock
- Anaphylaxis
- Sepsis
- Renal artery stenosis
- Dehydration
- Bilateral cortical necrosis

Intra-renal:

- **Acute tubular necrosis:**
  - Haemolysis
  - Rhabdomyolysis
  - Contrast nephropathy
  - Heavymetals
  - Pesticides

- **Glomerulopathy:**
  - Post streptococcal

- **Auto immune:**
  - Systemic lupus erythematosis
  - Good pauster syndrome
  - Henochschonleinpurpura
  - Haemolytic uremic syndrome
- **Papillary necrosis:**
  - Diabetes mellitus
  - Sickle cell disease
  - Analgesic abuse
- **Vascular causes:**
- Hypertension
- Vasculitis

Chronic Kidney Disease (CKD):

Pre-renal:

- Renal artery stenosis
- Chronic dehydration
- Congestive heart failure,
- Cirrhosis

Intra-renal:

- Common causes:
  - Diabetic nephropathy
  - Hypertensive nephropathy
- Others:
  - ADPKD
  - Oxalosis
  - Renal tubular acidosis
  - Analgesic nephropathy

Post-renal:

- Ureteric reflux
- Retroperitoneal fibrosis
- Chronic calculus disease
- Posterior urethral valve
- Prostatism
- Neurogenic bladder

Glomerular filtration rate:

Glomerular filtration rate (GFR) is considered as the best measure for level of kidney function.[3]

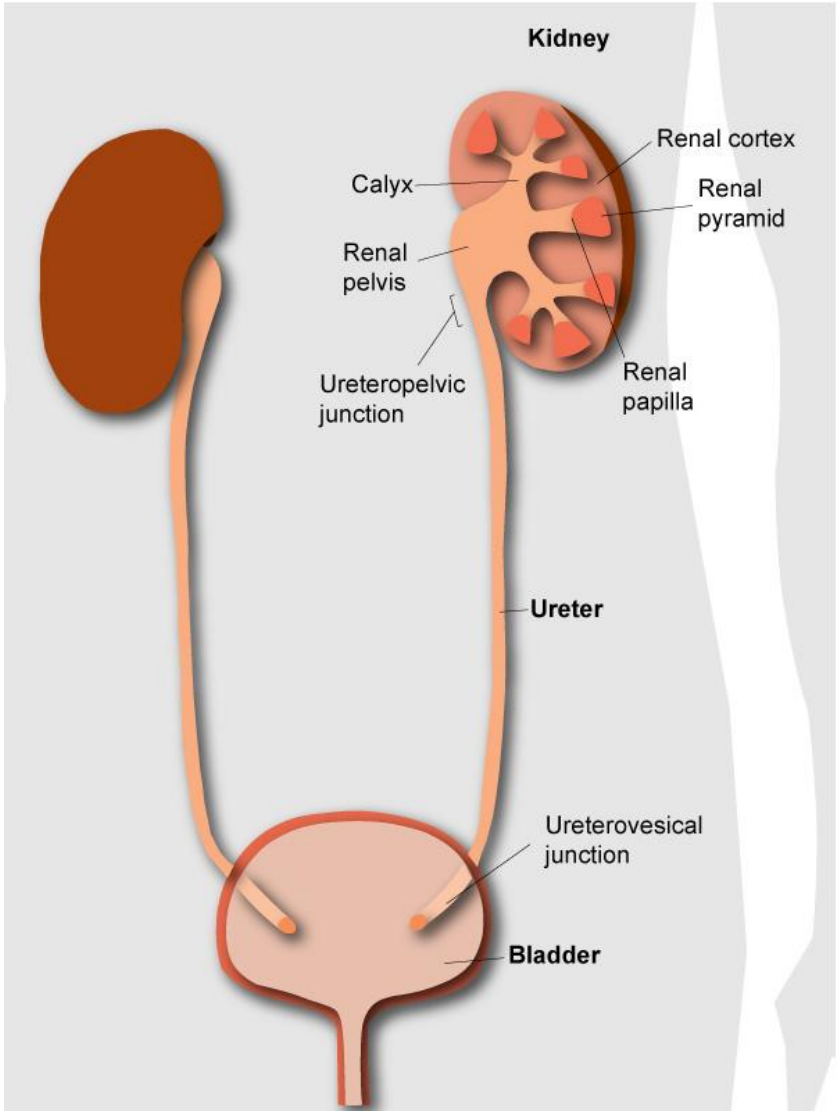
Factors affecting GFR which include:

- Age
- Sex
- Body size
- Race
- Weight

The National Kidney Foundation provides GFR-calculator for measuring the glomerular filtration rate. (Serum creatinine level is needed).

Renal Anatomy & Physiology:

Renal system contains two kidneys, two ureters, a bladder and a urethra.



The main function of kidneys: 1.Removal of metabolic waste products 2.Maintainance of fluid and electrolyte balance.

Additional role:

- Control Blood Pressure
- R B C Synthesis
- Calcium Metabolism
- Acid- Base Balance

Renal dysfunction will cause impairment of these functions.

Anatomy:

Kidneys located in the retro-peritoneum at the level of T12 and L3 on either side of the vertebral-column.

Normal Size: 9x13cm

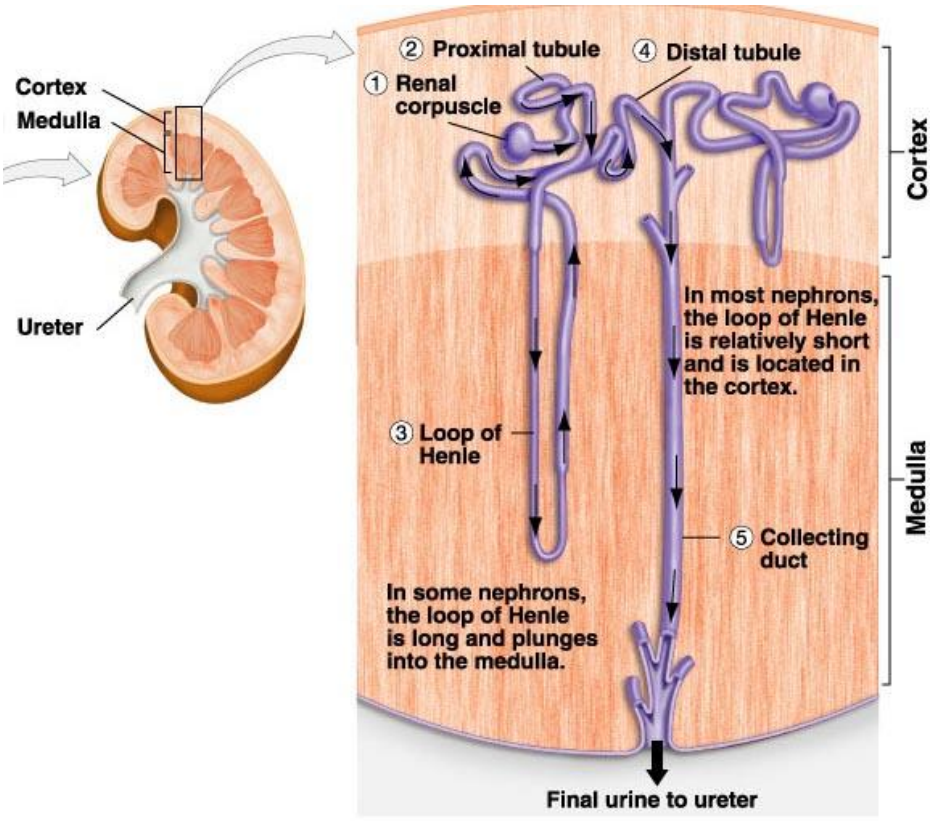
Usually right kidney will be lower level than the left.

Compared to the left kidney right kidney will 0.5to 1.5cm smaller in size.

Both kidneys moves well with respiration.

Outer part –cortex

Inner part - medulla



The outer layer of kidney is Cortex which contains:

- Glomerular apparatus
- PCT-Proximal Convoluted Tubules
- Loops of Henle(cortical part)
- DCT-Distal Convoluted Tubules
- CD- Collecting Ducts

The internal layer of kidney is Medulla which is made up of Renal Pyramids and it contains:

- Loops of Henle (medullary part)
- Collecting Ducts

Pyramids converge to form a minor calyx (6-14). Minor calyxes combined to form the major calyx (3-5).

Major calyces combine together form funnel shaped renal pelvis. The renal pelvis continues as the ureter and enters into the bladder.

Nephrons:

Nephrons are functional unit of kidneys. Approximately1.5 million nephrons present in each kidney.

Nephrons are of 2 types:

Cortical Nephrons -80%

- Excretory and regulatory functions

Juxtra-medullary Nephrons: - 15 %

- Main function is concentration and dilution of urine

Formation of urine:

Urine formation consists of 3 steps:

- Glomerular Filtration
- Tubular Reabsorption
- Tubular Secretion

Pathology involving the renal parenchyma will leads to renal dysfunction. Monitoring of the renal function will provide degree of progression of dysfunction. The regular assessment of renal-function is ideal for treatment in renal disease.

Monitoring of renal function:

Bio chemical monitoring: [3]

- Serum creatinine (S Cr)
- Blood urea
- eGFR-Estimated glomerular filtration rate (from creatinine clearance)
- Urine: albumin, sugar, 24 hours protein creatinine ratio

Normal values:

Blood urea	:	<40mg/dl
Serum creatinine	:	0.8-1.4 mg/dl

Glomerular Filtration Rate:

GFR calculator is useful for estimating the renal function. The efficiency or functioning level of the kidneys can be estimated by different formulas. All of the formulas contain the blood value of "serum creatinine", because the concentration of serum creatinine in the blood correlates inversely with the function of kidney.

GFR Measured as : ml/min/1.73m^2

If kidney function decreases, serum creatinine increases .So kidney function can be estimated routinely from the measurement of creatinine levels in the blood.

1. **Cockcroft-Gault** - formula is frequently used for estimating the creatinine clearance. The estimated creatinine clearance correlates well with the GFR, which is ideal marker assessment of renal function. [21]

GFR calculator:

Cockcroft-Gault method: (140-age) x (wt in kg) x(0.85if female) / (72*cr)

2. **Modification of Diet in Renal Disease Study:**

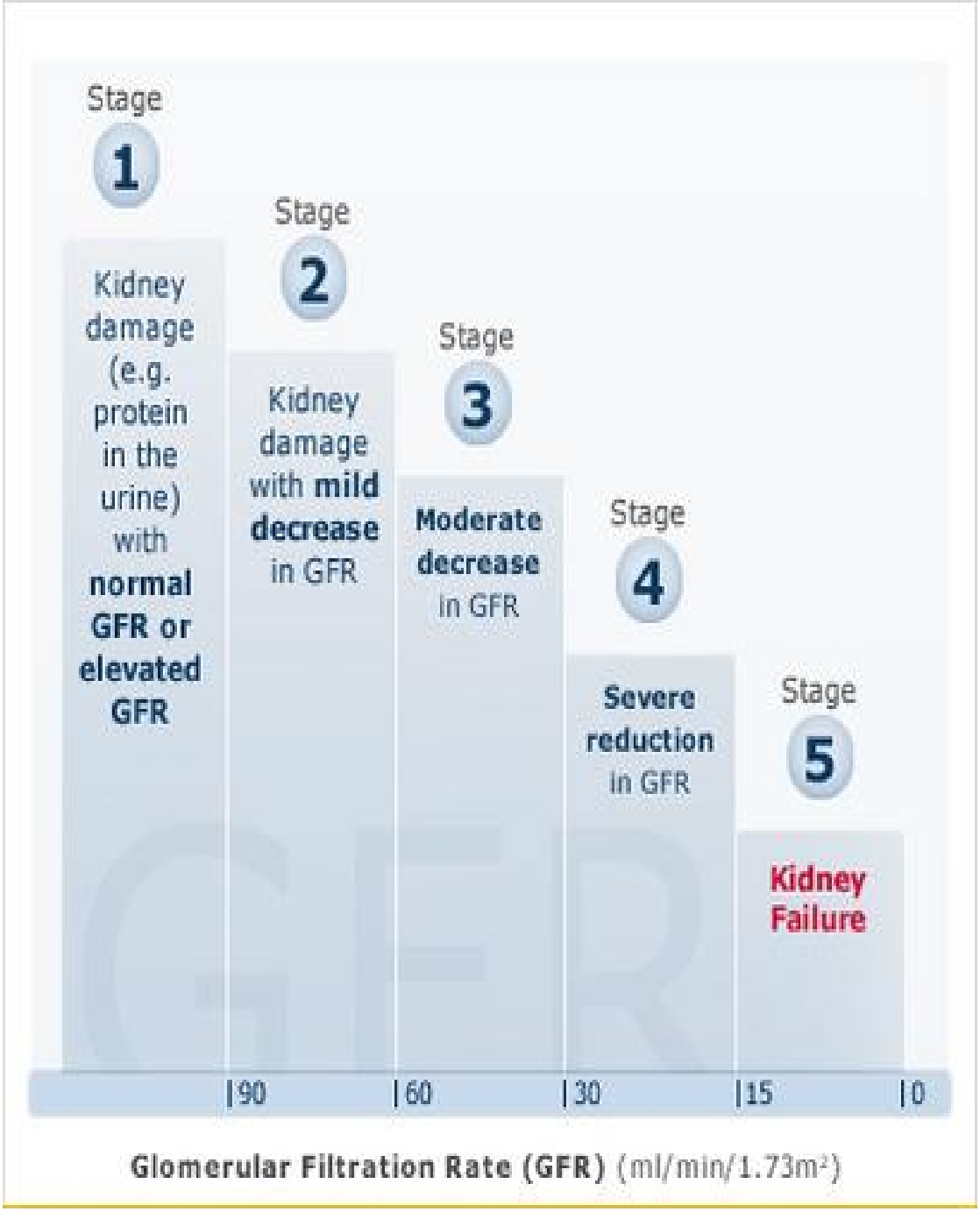
MDRD FORMULA**:**

eGFR = 186 x (Creat / 88.4)-1.154 x (Age)-0.203 x (0.742 if female) x (1.210 if black)ml/min/1.73m^2.

Measurement for CKD

Using the e-GFR, chronic kidney disease is categorised into 5 stages by NKF-KDOQI Guidelines [1.]

Glomerular Filtration Rate (GFR)	**Stage**	**Description**
More than 90	Patient in increased risk	**Risk factors** : - DM,HTN, family history, old age
Above 90	ONE	Kidney damage (protein in the urine) and **normal** GFR
60 Up to 89	TWO	Kidney damage & **mild** decline in eGFR
30 up to 59	THREE	**Moderate** reduction in eGFR
15 Upto29	FOUR	**Severe** reduction in eGFR
< 15	FIVE	**End Stage Renal Disease -ESRD** (dialysis or kidney transplant needed)



STAGES OF THE CHRONIC KIDNEY DISEASE WITH LEVEL OF GFR

Evaluation of renal function by imaging:[4]

Blood urea, serum creatinine, eGFR are indirect indicators of renal function which cannot measure the function each kidney separately.

Imaging plays a main role in evaluating the renal parenchymal disease due to the limitations in serum markers.

Imaging studies provides both the anatomic and the functional information of both the kidneys separately.

Imaging techniques:

- Plain radiography
- Conventional urography
- Ultra sonogram with Doppler
- CT urography
- MRI
- Radio nucleotide imaging

PLAIN RADIOGARPHY AND UROGRAPHY:

Plain radiograph provides little information mostly will show parenchymal calcification.

Urography provides variable patterns of nephrogram.

- **Immediate faint nephrogram**:
  - Chronic glomerular disease
- **Increasing dense nephrogram:**
  - Acute renal obstruction
  - Hypotension
  - Renal ischemia
  - Acute glomerular disease
  - Intra-tubular obstruction
  - Renal vein thrombosis
- **Immediate dense persistent nephrogram:**
  - Acute tubular necrosis
  - Severe inflammatory renal disease

Conventional excretory urography necessitates contrast administration and should be used cautiously in renal dysfunction patients and it involves ionising radiation.

Ultrasonography:

USG is the initial mode of imaging for renal dysfunction.

- 3-5 MHZ transducer is used
- Non-invasive
- Non-ionising radiation
- Easily differentiates obstructive from the non-obstructive cause

Normal appearance:

Renal size echogenicity, cortical thickness, parenchymal thickness and hydronephrosiscan be made easily.

Normal renal cortical echoes are less than that of the liver.

Medulla appears as echo poor oval areas evenly distributed along the inner margin of the cortex.

Cortical thickness: Distance between the capsule and the outer margin of medullary cortex.

Parenchymal thickness: Distance between the capsule and the margin of sinus.

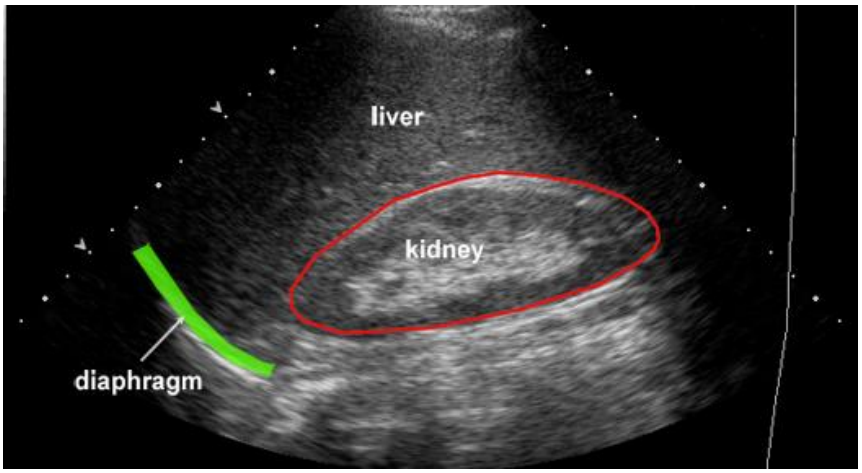
Renal sinus appears as bright which contains calyces, infundibulum, portion of renal pelvis, fat, vessels, lymphatics.

Neonatal kidneys appear more echogenic than adult kidneys.

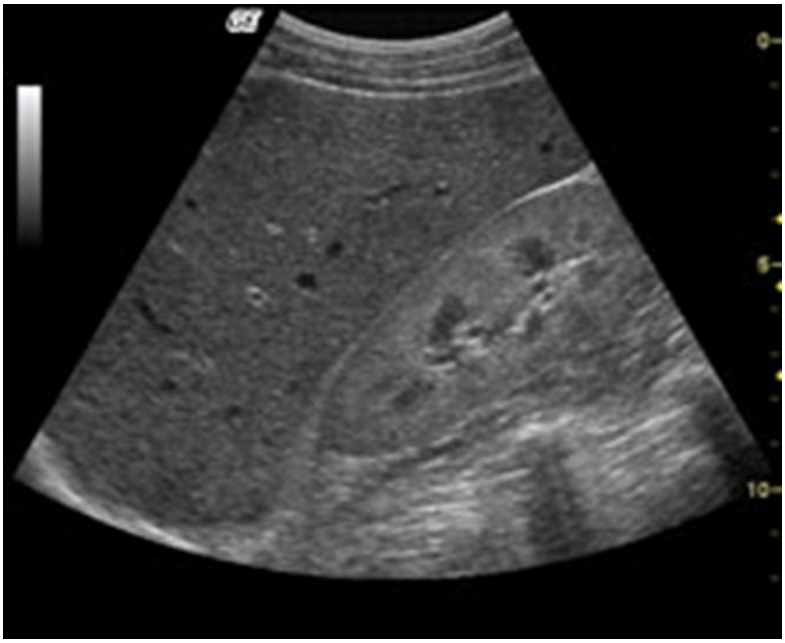
In renal parenchymal disease there will be, decreased size of the kidneys(<8cm) increased echoes, loss of cortico-medullary differentiation will be there.

In acute kidney disease, kidneys may be enlarged while in the chronic dysfunction, kidneys are shrunken.

Ultra sound is useful for follow up of progression.



Normal kidney: cortex appear hypo echoic with cortico medullary differentiation.



Patient with renal failure shows increased cortical echoes and loss of cortico medullary differentiation.

Colour Doppler:

Non-invasive, easily available tool for evaluating the renal vessels.

Renal arteries arises from the abdominal aorta, slightly below the origin of SMA which divides into anterior and posterior division and these further divides into segmental branches, inter-lobar branches and arcuate arteries. There may be accessory renal arteries.

Technique:

Patient in supine, right renal artery is traced just below the superior mesenteric artery.

Left renal artery is arising postero-lateral to Aorta just below the superior mesenteric artery.

Hilar, segmental and inter-lobar arteries can be demonstrated in all patients while arcuate and striate arteries seen only in thinner patients.

Optimum pulse repetition frequency should be used to detect moderate flow velocities.

Normal Doppler patterns:

Renal arterial Doppler will show rapid systolic upstroke, followed by a secondary slower rise to systole, followed by diastolic decay with persistent diastolic forward flow.

Spectral indices are measured in the renal artery at proximal middle and at hilar level. Further indices are measured in the intra renal vessels at superior, middle and inferior pole.

Branching pattern of renal vessels, spectral wave pattern of intra renal vessels can be made. Vascular resistive index (RI), Pulsatility index (PI)are measured.

Resistive Index-RI : PSV-EDV/ PSV.

Peak systolic velocity-PSV

End diastolic velocity-EDV

Normal indices	
Pulsatility(PI) index	0.7-1.4
Resistive index(RI)	0.58-0.7
Peak systolic velocity(PSV)	60-140cm/sec
Renalartery/ aorta ratio	<3.5
Acceleration time	0.04-0.05
Acceleration index	2.5-3.8m/sec^2

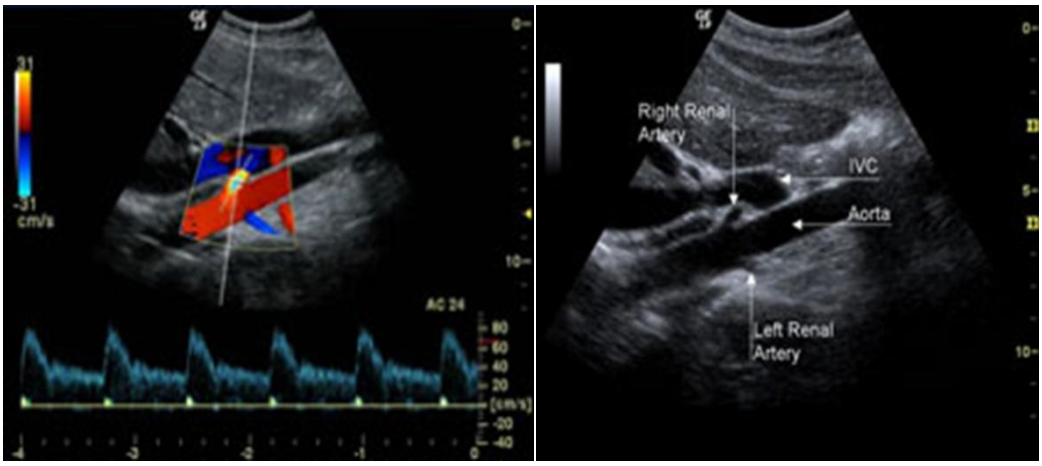
Parenchymal disease with tubulointerstitial, vascular involvement will have high RI values>0.7.

In case of parenchymal disease due to glomerular lesion will not show any increase in the RI values.

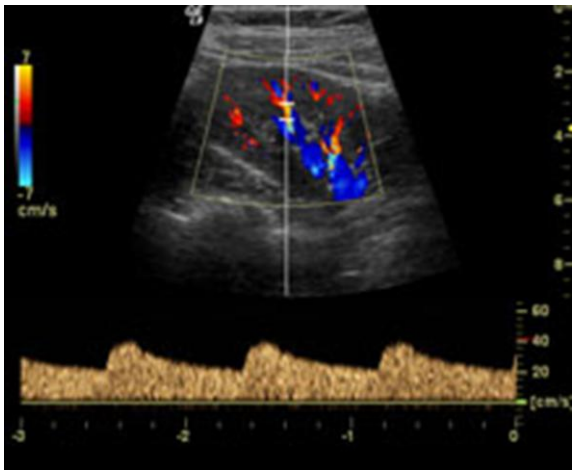
Elevated RI values correlate well with severity of disease in SLE, HUS, and hepato-renal syndrome.

Normal renal Doppler:

Normal major renal vessels showing normal arterial pattern



Normal intra renal Doppler spectral pattern. Rapid systolic upstroke followed by persistent continuous diastolic flow.



Computed tomography:

It provides size, calcification, and obstruction of renal system. On contrast it will show various nephrographic pattern and excretory function similar to excretory urography. But contrast studies is harmful in impaired renal function.

Magnetic resonance imaging(MRI):[4]

- Non-ionising
- Multi-planar capability

MRI evaluation of the kidneys include:

- Axial, coronal T1 weighted imaging
- T2 weighted imaging

- Gradient, in-phase- opposed phase imaging
- MR-Renography:
- Dynamic contrast imaging following administration of contrast.
- Diffusion weighted imaging.

Cortico-medullary differentiation will be seen in T1 & T2 weighted imaging.

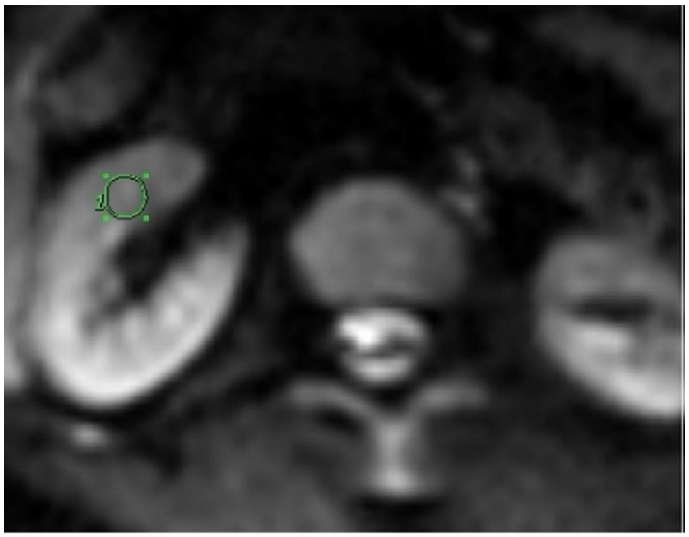
Normal kidney cortex will be showing higher signal intensity in the T1, medulla will be hyper-intense in T2 imaging.

Cortex will be slightly hypo-intense in T2 because it contains less water.

Sinus fat appears bright on both T1 and T2.

Loss of cortico-medullary differentiation will be seen in medical renal disease which is well correlating with serum creatinine level more than 3.0mg/dl.

Some studies exploring the addition of DWI in renal dysfunction demonstrates low Apparent Diffusion Co-efficient (ADC) values.



MEASUREMENT OF ADC VALUES FROM DIFFUSION WEIGHTED IMAGING OF THE KIDNEYS

Angiography:

Renal angiography has limited role in parenchymal disease. It will be useful in renal artery stenosis, PAN.

Radio nucleotide imaging:

Scintigraphy provides both structural and functional aspect of the kidneys. Radio-nucleotides are excreted in the kidneys so these should be used cautiously in renal failure patients.

CT and USG can give better anatomic details but less functional status.

USG shows increased in renal echogenicity, decrease in size, obstruction, but its accuracy depends on operator efficiency and subjective variation.

For CT iodinated contrast material, which is not advisable in patients with renal dysfunction.

MRI gives good structural and Functional information and no radiation exposure to the patient.

fMRI - Functional MRI imaging modalities like diffusion-weighted imaging(DWI), blood oxygen level-dependent (BOLD) imaging and contrast enhanced MR-urography will be useful in the assessment of renal function.[4]

Diffusion-weighted Imaging (DWI): It is a non-ionising and non-invasive imaging modality which works on the basis of the movement of tissue water molecules at cellular level.

Apparent Diffusion Co-efficient (ADC):It is a quantitative parameter derived from diffusion weighted imaging that combindly gives the detail of both capillary perfusion and water diffusion.

Diffusion weighted imaging in kidneys will be useful in assessing the renal function because it has increased blood flow and regulates water fluid and electrolyte balance.

DW-MRI in renal disorder is upcoming area and preliminary studies were done to characterise the renal lesions, renal parenchymal disease and renal infections.

There is less number of studies which correlates the relationship of ADC values, Renal-Resistive Index (RI) with serum markers of renal dysfunction and with different stages of CKD.

There is no fixed ADC cut off value to identify stage of renal dysfunction.

AIM

AIM

TO STUDY THE RELATIONSHIP OF APPARENT DIFFUSION COEFFICIENT (ADC) VALUES OF RENAL PARENCHYMA AND RENAL RESISTIVE INDEX (RRI) WITH SERUM MARKERS OF RENAL DYSFUNCTION AND STAGE OF CHRONIC KIDNEY DISEASE

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Study by **Toya *et al***[16] had found People who has lower eGFR tend to have lower ADC values but this study cannot a show significant correlation between mean ADC values of renal parenchyma and eGFR.

Mohamed *et al* had observed ADC value is affected in renal parenchyma of patients with hepato-renal syndrome and not affected in the presence of refractory ascites in liver cirrhosis. Duplex-Doppler examination of intra-renal arteries enables the early identification of hemodynamic disturbances of kidneys in patients with liver cirrhosis.[23]

Namimoto *et al* had proposed ADC values of kidneys (both medulla and the cortex) failure patients were significantly lower .Patient who has normal renal function showed high ADC valies.[25]

Thoeny *et al* had stated that in patients with normal renal function, the calculated ADC was observed in the cortex is higher than in the medulla ($P < .001$). But there is no significant difference observed between the calculated ADC of the medulla and in the cortex in patients who has renal failure.[24]

Theoneyet also stated that in patients with renal failure had significantly lower (P < .001, P = .004) calculated ADC of cortex and medulla than who has normal renal parameters persons.

Xu *et al* found that the ADC values of diseased kidneys were much lower than in normal kidneys, and also stated a positive correlation between the eGFR and ADC values .[15]

In their prospectively study the application of diffusion-weighted (DW) magnetic resonance (MR) imaging to assess the renal function in patients with CKD was attempted.

72 normal persons and Forty three patients underwent a DW-MR imaging (coronal) of the kidneys .The patients were grouped in to 5 stages as according to the KDOQI CKD guidelines .

Apparent diffusion coefficient (ADC) values of the kidneys were measured using higher b values (b = 500). ADC values are compared between the patients and normal persons.

They didn't find any difference in the ADC values of the cortex and the medulla in the normal persons.

CKD patients having significantly low renal ADC (t = -4.383, P = 0.000) when compared to the volunteers.

The ADC values renal dysfunction shown decreasing in trend than in volunteers with normal renal function all stages of the CKD, except stage 1 CKD.

They also found that a inverse correlation between the renal ADC and serum creatinine level among the CKD patients.

They concluded that the Diffusion-Weighted MRI will be the feasible technique for assessing of the function of the kidneys, especially to detect renal failure in the early stage.

Toya *et al* found the significant difference between the estimated glomerular filtration rate (eGFR) and the (ADC) values of the kidneys.[16]

The mean ADC values of the group with eGFR<30 mL were 1.70 $\pm$ 0.18 and for those with eGFR > 30 were 1.87$\pm$0.11.

The ADC values were significantly low if the eGFR<30 compare to other groups ($P<0.05$).

Person et al with lower eGFR tend to have a lower ADC values. However, there was no significant correlation was found between the mean ADC values and the eGFR.

Sandrasgaran *et al* found that benign lesions had higher ADC values and the malignant lesions higher ADC Value with the mean ADC being 2.72 Vs 1.88 x $10^{-3}mm^2/s$ respectively.[23]

They also found that benign cysts (31) shown significantly higher ADC than malignant cysts (2.7 Vs 2.02 x $10^{-3}mm^2/s$ respectively; $p < 0.001$).

Platt *et al* compared the resistive index (using the duplex Doppler waveform) with the clinical and laboratory findings and with the results of renal biopsy in 41 patients with non-obstructive medical renal disease patients who had kidneys with active tubulo- interstitial disease and also noted an increased mean RI (0.75 ± 0.07) was statistically significant ($p < .01$) comparing the RI in the kidneys with glomerular pathology (RI: 0.58 ± 0.05). [26]

ATN showed an elevated RI ($>0.78 \pm 0.03$) and also in vasculitis / vasculopathy there is an increased RI (mean RI = 0.82 +/- 0.05).

Patients with hypertension, proteinuria or haematuria have kidneys with a significantly higher RI than patients without these clinical factors.

Ultrasound showed kidneys were abnormally echogenic and did not have an increase in the RI significantly different from kidneys of normal echogenicity.

They also found a weak correlation between the RI and the creatinine value with a linear correlation coefficient of 0.34. In the patients with normal renal RI, the mean creatinine level was 1.7 ± 1.7, while in those with abnormal RI values (greater than or equal to 0.70) the mean creatinine level was 3.7 ± 3.6.

They had concluded that some forms of the non-obstructive renal disease can produce changes in the Doppler waveform and an increase in the RI. The values of Doppler waveform changes are affected by the site of the main disease within the kidneys. The tubulo-interstitial compartment disease such as acute tubular necrosis, interstitial nephritis and vasculitis were generally had in elevated RI. Whereas glomeruli disease, no matter how severe it is, did not show elevation in RI significantly. Stage of the renal dysfunction as indicated by the serum creatinine level probably affects the Doppler waveform to a lesser extent, but the relationship noted is weak.

Rosenfield *et al* using B scans had graded echogenicity of renal cortex by comparing the echoes of liver, spleen, and renal sinus.

25 patients examined immediately before renal biopsies. They observed no positive correlation between the nature and the severity of the glomerular pathology on renal biopsy and to the cortical echoes findings.

They also noted maintenance of cortico-medullary differentiation is not corresponded with any pathological finding.

They found there is positive correlation among the nature and severity of the interstitial changes on biopsy and to the cortical echogenicity on USG. Interstitial diseases produce a increase in renal cortical echoes. A greater increase cortical echoes was observed in diffuse scarring, and cortex of the patients who had active interstitial pathology has most intense echogenicity.

Ankur Goyal *et al* had found the ADC values of renal failure patient were significantly lower than in persons with normal. (2.113 ± 0.285 vs. 2.319 ± 0.1246). [19,27]

ADC values lesser than 2.0354 ($\times 10^{-3}$ mm^2/ s) was associated only with renal dysfunction and ADC values higher than 2.4516($\times 10^{-3}$ mm^2/ s) seen in patients with normal kidney function only.

They concluded that there is significant negative association among the ADC values of renal parenchyma with sr. Creatnine, blood urea (R= -0.50) and there is significant positive correlation (R = 0.784) when comparing with estimated glomerular filtration rate (eGFR).

They also statistically significant decrease in ADC values while advance of the CKD.

Zhao *et al* had noted cortical and medullary ADC values of the CKD group were significantly lower when compared to those normal. In CKD patients, a negative correlation was observed between ADC values of the cortex and serum creatinine and significant positive association was found between the cortical ADC and the eGFR.

They also observed that there is significant inverse correlation among medullary ADC values and serum creatinine, ADC values of the kidneys were significantly correlated well with histo-pathological fibrosis score.

Using MR diffusion tensor imaging (DTI) ,Wang *et al* found that ADC of normal cortex ($2.387 \pm 0.081 \times 10^{-3}$ mm^2 /s) was significantly higher than that of medulla ($1.990 \pm 0.063 \times 10^{-3}$ mm^2 /s)in normal kidneys. The Fractional Anisotropy (FA) value in normal renal cortex

was significantly lower (t=-42.713, P=0) compared to the of medulla (0.447±0.022).

ADC and Fractional Anisotropy values of the LT renal cortex (2.40±0.082 × 10^{-3} mm^2 /s, 0.282±0.017) and medulla (2.002±0.081 × 10^{-3} mm^2 /s, 0.452±0.024) was not differ significantly compare to RT renal cortex (2.36±0.080 × 10^{-3} mm^2/s, 0.283±0.018) and medulla (1.978±0.039 × 10^{-3} mm^2/s, 0.443±0.019).

Values for the ADC (×10^{-3} mm^2 /s) and FA in 12-hour fasting, 4-hour fasting, non-fasting and water diuresis states were 2.372±0.095 and 0.278±0.018, 2.387±0.081 and 0.282±0.017, 2.416±0.051 and 0.279±0.023, 2.421±0.068 and 0.270±0.021 respectively in cortex, 1.972±0.084 and 0.438±0.014, 1.990±0.063 and 0.447±0.022, 2.021±0.081 and 0.450±0.031, 2.016±0.076 and 0.449±0.028 respectively in medulla. The FA and ADC values of were not differing significantly with the hydration status.

They concluded that Diffusion Tensor Imaging of kidneys is feasible with highly reproducible, ADC and FA values were not differing much with hydration states.

Thoeny *et al* studied the use of DWI magnetic resonance imaging other than the brain. Due to advanced improvements in the MRI

imaging with newer faster sequences, the need for non-invasive imaging without giving contrast injection in patients having renal failure can be solved successfully by using DWI technique.

DWI imaging is quantified by means of the apparent diffusion coefficient (ADC) values which gives simultaneous detail about both diffusion and perfusion.

DWI imaging will be used to detect the functional information of the kidneys. Impairment in the renal function is associated with decrease in ADC values.

Both Ureteric obstruction and the renal artery stenosis (RAS) result in a decreased ADC (will cause perfusion and diffusion changes in the affected kidney).

In pyelonephritis, there will be focal or diffuse signal intensity changes were seen with high-B-value images. The increased signal intensity corresponds to low ADC values.

DW I is a compatible and a comprehensive technique in patients with transplanted kidneys, shown promising initial results for the grading of transplant dysfunction.

DW MR showed that measurements are of good quality, with further improvements in this modality will be useful to detection of diffuse renal pathology at early stage and also for more accurately characterize the focal renal lesions.

Prigent *et al* had noted that CKD is associated with cardiovascular disease which leads to increase in mortality. Kidney Disease Quality Outcome Initiative (KDOQI) recommends estimation of eGFR for diagnosis and monitoring of CKD. [3]

GFR calculator were depends on the serum creatinine values in Adults Cockcroft-Gault [C-G] formula and Modification of Diet in Renal Disease [MDRD] study equations) and in children (Schwartz and Counahan-Barratt equations)).

Evaluation from the recent literature showed that the efficacy and relevance of these equations in terms of bias, precision and reproducibility in different specific indications like screening CKD, the prediction of these equations depends on Sr.creatinine which has limitations, specially who has near-normal GFR.

Cova *et al* in their study they evaluated the reproducibility and the reliability of the diffusion weighted -MRI in normal kidneys and variable renal lesions.

39 cases undergone MRI of the kidneys in a 1.5 Tesla super-conducting magnet.

Fat sat Axial turbo spin echo (FsTSE) T2 and coronal fast field echo weighted images were obtained in every patient.

Diffusion imaging done in the axial plane with 17 sec breath-hold with echo planar imaging (SE- EPI) single shot sequence , with high b value of 500 .

The ADC values were measured by drawing 1 cm circle both in the lesion and in normal renal parenchyma .

Normal renal parenchyma has ADC of 1.7×10^{-3} to 2.6×10^{-3}, and the simple cysts shows higher ADC values (2.8×10^{-3} to 4.0×10^{-3} mm^2 s^{-1}).

The ADC values of renal pelvis are high in hydro-nephrosis 3.39×10^{-3} to 4.00×10^{-3} mm^2 s^{-1}).

Pyo-nephrosis (3) ADC values of the renal pelvis was lower than compared to the renal pelvis of hydro-nephrotic kidneys (0.7×10^{-3} mm^2 s^{-1} to 1.07×10^{-3} mm^2 s^{-1}).

Solid benign and malignant tumors has low ADC 1.28×10^{-3} to 1.83×10^{-3} mm^2/s.

They concluded that diffusion-weighted MR imaging of the kidneys is a helpful in differentiating between the normal parenchyma and different renal diseases. This is preliminary study and further evaluation are needed.

Francesca *et al* had studied on the renal resistive index in variety of clinical settings like detection of allograft rejection, renal artery stenosis, estimation and progression of CKD, acute and chronic obstructive renal disease.

Recent results found there is an elevated renal RI reflecting the changes of intra-renal perfusion. Renal RI which is also related to hemo-dynamics in kidneys.

They concluded that measuring the renal resistive index has been advocated to detect progression and in management of patients with primary hypertension.

Galesić *et al* stated that Doppler assessment has been evolved as a non-invasive technique to evaluate the hemodynamic nature of main and intra-renal arteries in persons with variety of renal disorder. [28]

The importance of duplex Doppler USG in the measurement of resistance in the glomerular diseases had not been determined yet.

They evaluated renal vascular resistance in persons with glomerular disorder by measuring intra-renal arterial resistance (RI) and correlated RI with renal functional tests and other clinical and lab details.

They found that Doppler parameters were correlated with the histo-pathological changes in the kidneys who undergone the percutaneous biopsy.

Pulsed Doppler sonography was used to measure RIs of the intra-renal arteries in fifty patients with glomerular pathology and sixty normal control subjects.

The renal vascular resistive index (RRI) was determined by the use of Doppler sonography. Compared to the normal controls the mean RI of patients with glomerular pathology was 0.68 ± 0.09 which was statistically significantly high.

In a group of subjects with membrano-proliferative glomerulonephritis the mean RI measured was 0.817 ± 0.624 which was statistically significant higher when comparing other groups of glomerulonephritis.

The renal vascular resistance index RI has positive correlation with serum creatinine, creatinine clearance and β2 micro-globulin.

Qualitative duplex USG measure of renal arterial RI does not appear to be reliable in different types of glomerulonephritis.

Angelini*et al* had found Ultrasonographic study of the urinary tract in nephrological conditions gives the right assessment of many clinical conditions.

USG allows a better real-time examination of the parenchymal lesions, obstructions and tumours. But the differential diagnosis of the parenchymal nephropathies appear more difficult due to the fact that different histological pictures may present similar ultrasound findings.

Colour-Doppler is a valid integration of the conventional US B-mode technique for the measurement of indirect parameters such as the resistance index (RI) and the pulsatility index (PI).

It seems that the RI values higher in patients nephropathies due totubulo- interstitial or vascular causes than in due to glomerular cause.

It is still debated that the relationship between RI and the progression of the renal damage. In the past years the RI values have gained popularity as a vascular compliance.

Jörg *et al* found the progression of renal dysfunction rely on the various clinical parameters such as hypertension and proteinuria.

They had shown that an increase in the renal resistive index measured by duplex Doppler had been associated with a poor prognosis in renal artery stenosis.

The progression of renal disease in patients with renal artery stenosis significantly correlates with renal resistive index >0.80.

RI was measured in segmental arteries of both kidneys. Creatinine clearance was measured at 3, 6 and 12 months and then at yearly intervals thereafter.

Twenty five patients had a renal resistance index (RI) value ≥ 80 at baseline of which nineteen had a decrease in renal function; sixteen (64%) progressed to dialysis and 6 (24%) expired.

On comparing in patients with renal resistance index values <80, thirteen (9%) had a decline in renal function, only seven (5%) became dialysis-dependent and two (1%) died with P< 0.001.

They had concluded that patients with renal RI value of ≥ 80 are at risk of progression of the kidney disease.

MATERIALS AND METHODS

MATERIAL & METHODS

Methodology:

Design of study:

- Prospective observational study
- Sample size-100 patient
- Study period - 6 months
- Study centre- Barnard institute of radiology,
- Rajiv Gandhi Government General Hospital, Madras medical college

Inclusion criteria :

- Patients who has elevated renal parameters Serum creatinine>1.5mg/dl , Blood urea >40mg/dl along with patients with normal renal function.
- Patient who comes for renal Doppler examination.
- Patient who comes for MRI abdomen for renal and non- renal lesions

Exclusion criteria

- Non consenting patient
- Patient who cannot breath hold

Study:

It is a single-institutional prospective study in Rajiv Gandhi govt General hospital. Approval got from by institutional ethical committee. The informed consent from the patients and controls have been obtained .

Patients who came for MRI abdomen and spine both non renal and the renal disorder and to renal Doppler study with normal and elevated renal parameters were identified and included in the study.

Diffusion weighted imaging and Renal Doppler study was performed of all patients with elevated renal parameters and in patients with normal renal parameters.

The cases are divided based on the presence of renal dysfunction, with cut off value for Serum Creatinine (sr.cr)> 1.5 mg/dl.

Totally 100 patients with both renal dysfunction and normal serum renal parameters were identified .

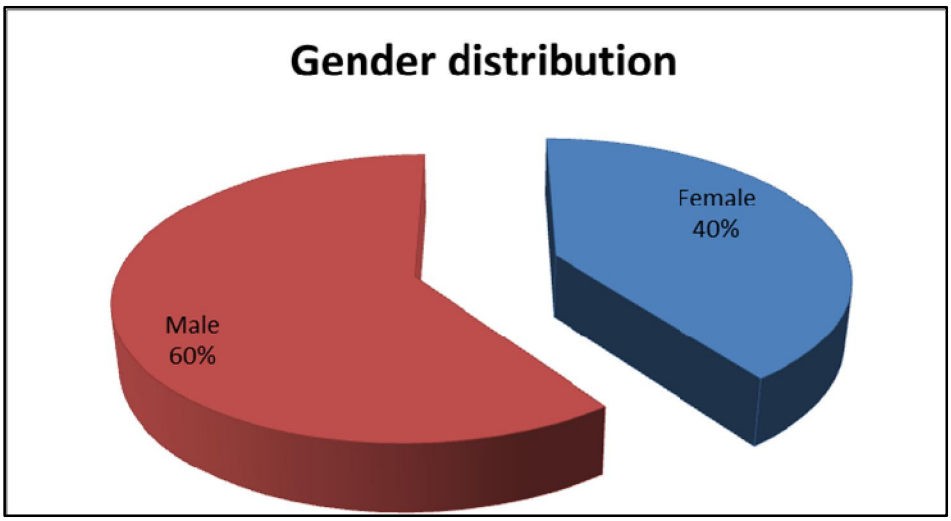
Mean Creatinine Level for group with the renal dysfunction group was 3.7 mg/dl (range 1.6-12.4 mg/dl) and mean Blood Urea was 58.4 mg/dl (range 30-140 mg/dl).

We have not selected the patients as acute and chronic kidney disease as separate entity.

Patients were classified into stages based on the disease severity, as per the level of serum creatinine and blood urea level.

Data including age , sex, clinical, and laboratory parameters were collected.

eGFR was calculated by using C-G formula.



We selected the patients only based on the elevated renal parameters.

TECHNIQUES:

Magnetic Resonance Imaging :

All the persons examined under 1.5‑Tesla MRI scanner (Siemens-Germany) in supine placing a body coil over the abdomen .

Body coils with six element matrix were placed on the abdomen anteriorly in addition with two posterior spine coils for better SNR(signal‑to‑noise).

Imaging protocol:

1. Localizer: True (FISP) - True Fast Imaging and Steady Precession in the axial and coronal sequences used as localizer to plan the Other sequences.
2. Conventional MRI sequences:

a. Axial T1W

b. Axial and coronal T2 FS sequence.

3. IN phase opposed phase imaging
4. Diffusion Weighted - MR imaging (DWI) with b values of 0, 250, 500.

DWI IMAGING:

DWI is Respiratory triggered Fat suppressed axial diffusion-weighted sequence with b-values of 0, 250 and 500 s/mm^2.

The physical parameters comprises of:

TR/TE = 4100/14

Slice thickness = 5mm

Receiver Bandwidth = 952

Field of view =230

Acquisition time = 2 min (depends on patient's respiratory rate).

DWI is Respiratory triggered using the navigator-trigger prospective acquisition correction technique –PACE, the position diaphragm is assessed periodically by the navigator echoes.

Apparent Diffusion Coefficient (ADC)maps were derived automatically on a voxel-by-voxel basis.

A quality of Diffusion Weighted images and the A DC maps were obtained.

Renal Doppler study:

Renal Doppler study was done by using 3-5 MZ probe in the sonoscape machine.

Resistive -index (RI) of the intra renal parenchymal vessels have been taken in the segmental/interlobar vessels in the upper , mid lower pole. Good quality wave forms taken and spectral analysis done.

Segmental/ interlobar arteries were examined using a 2- to 5 mm gate with Doppler angle of 0- 60*.

Wave forms were optimized for measurement Resistive Index .Lower pulse repetition frequency (PRF) used without any aliasing to maximize waveform size , with high gain with good obscuring background and the lowest wall filter .

At each level 3 to 5 reproducible wave forms from the intra renal arteries were obtained.

RIs from these waveforms traced manually and are average value was taken.

Mean RI for each kidney were measured.

(RI: Peak Systolic Velocity-End Diastolic Velocity / Peak Systolic Velocity)

OBSERVATION AND RESULTS

OBSERVATIONS AND RESULTS

IMAGE ANALYSIS:

DWI imaging and ADC Measurement:

ADC values are measured quantitatively by placing region of interest of size 1 cm^2 in the commercial workstation .

Region Of Interest(ROI) is placed on renal parenchyma for measuring the ADC was done by drawing a circular over renal parenchyma(without any preference to cortex and medulla).

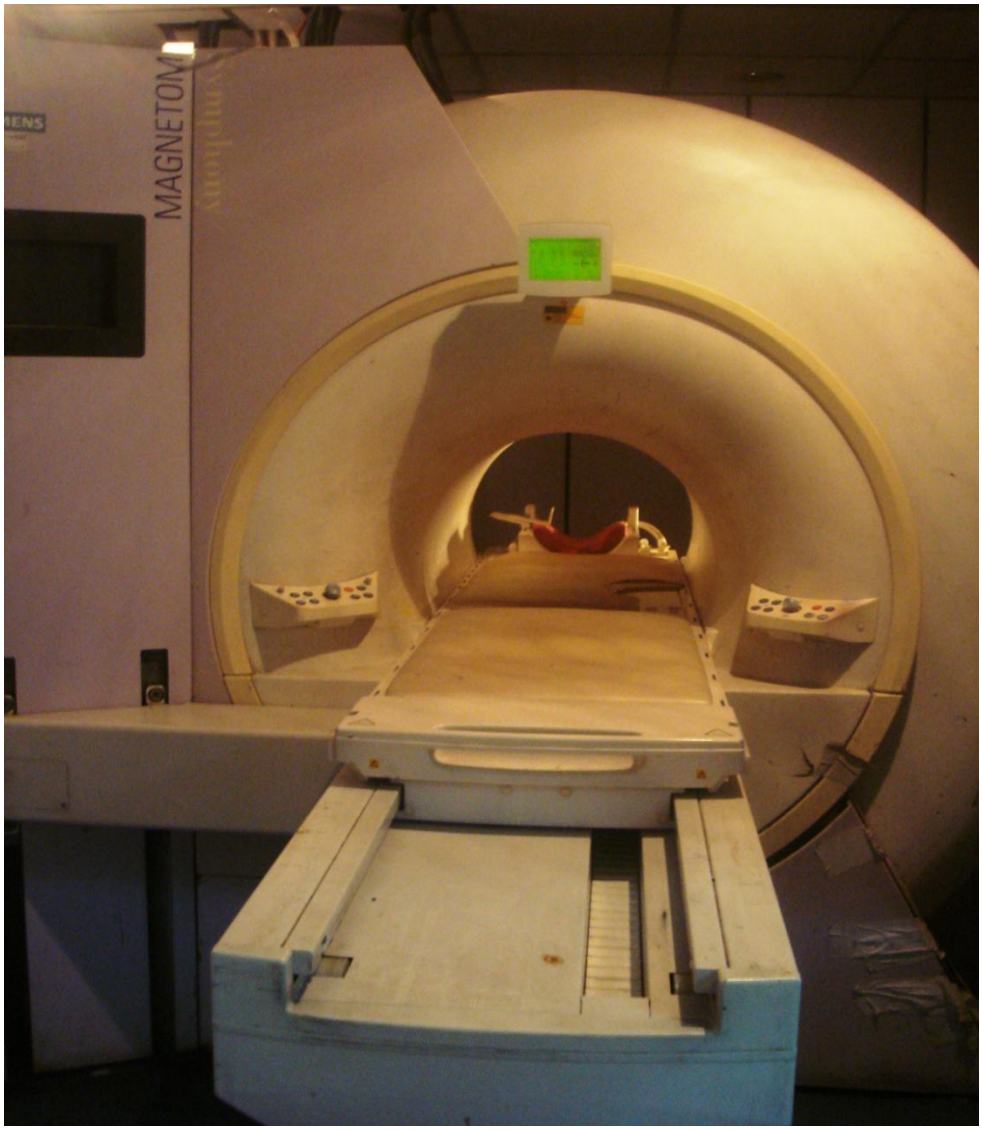
ADC values were not separately measured for the renal cortex and medulla, because it is hard to place the ROI cursor precisely in cortex and medulla especially patients with severely contracted kidneys

3 ROIs placed‑one each over the superior, mid‑polar, and lower polar region of each kidney separately. The mean ADC of these three values were calculated for each kidney separately.

The Apparent Diffusion Co efficient were measured as mean ± standard deviation ($A \times 10^{-3}$ mm^2/s).

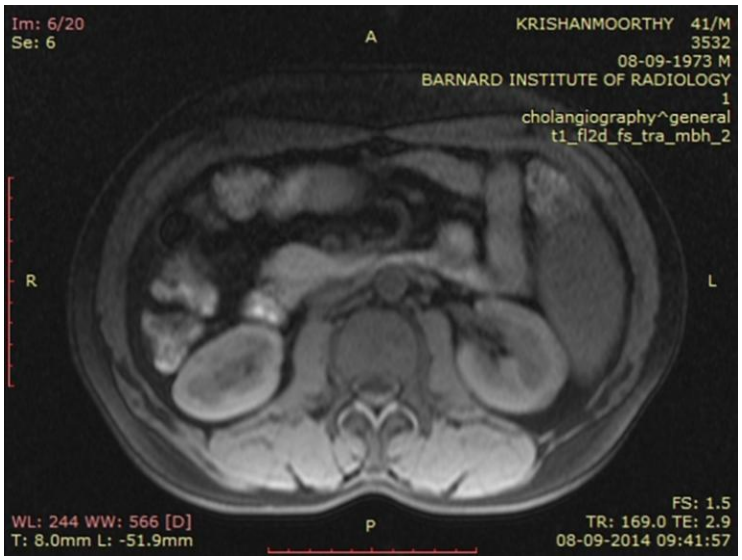
MRI

1.5 TESLA CLINICAL MAGNET, MEGNETOM SYMPHONY (SIEMENS)

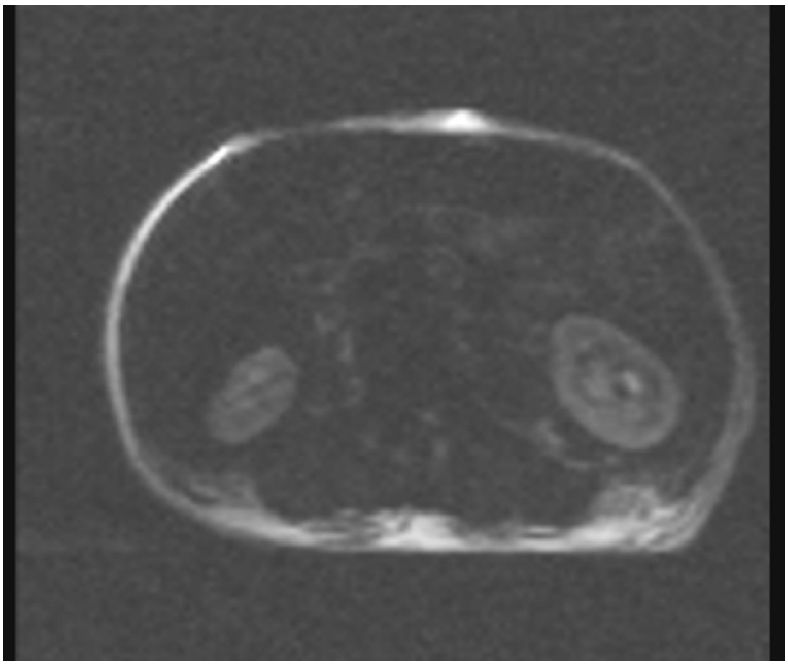


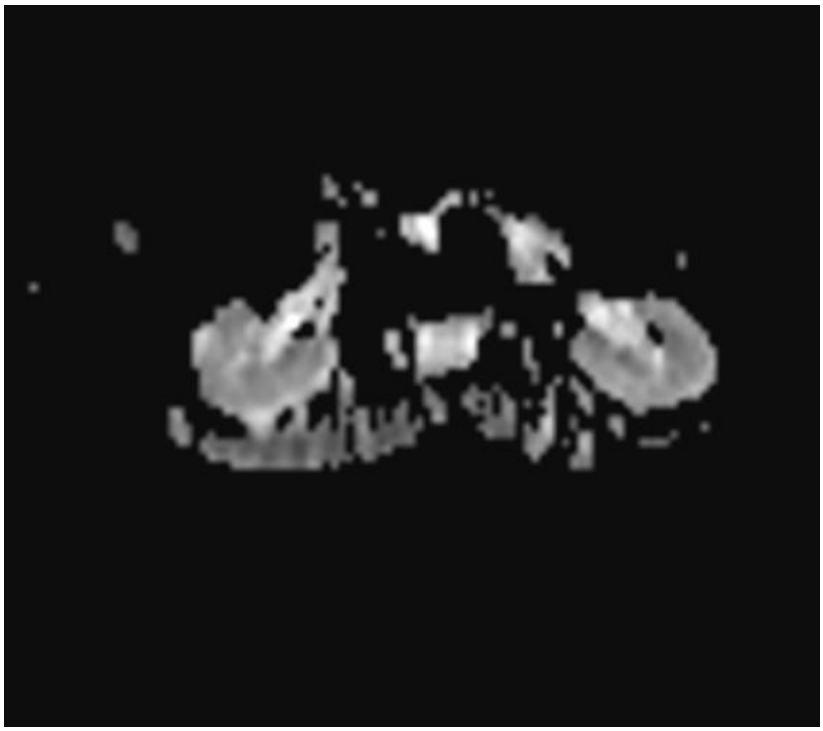
DIFFUSION WEIGHTED IMAGING

1.KRISHNAMOORTHY 41/M



Localiser T1& axial fat sat

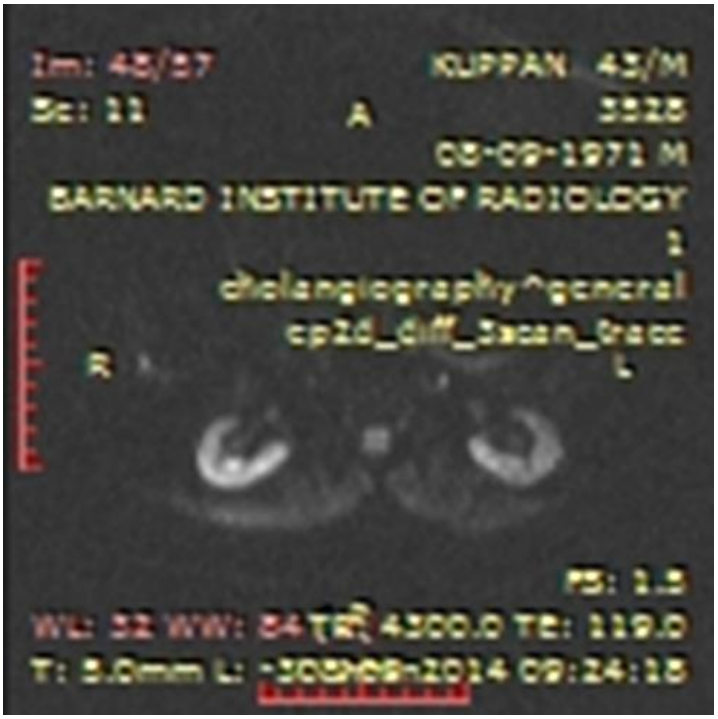


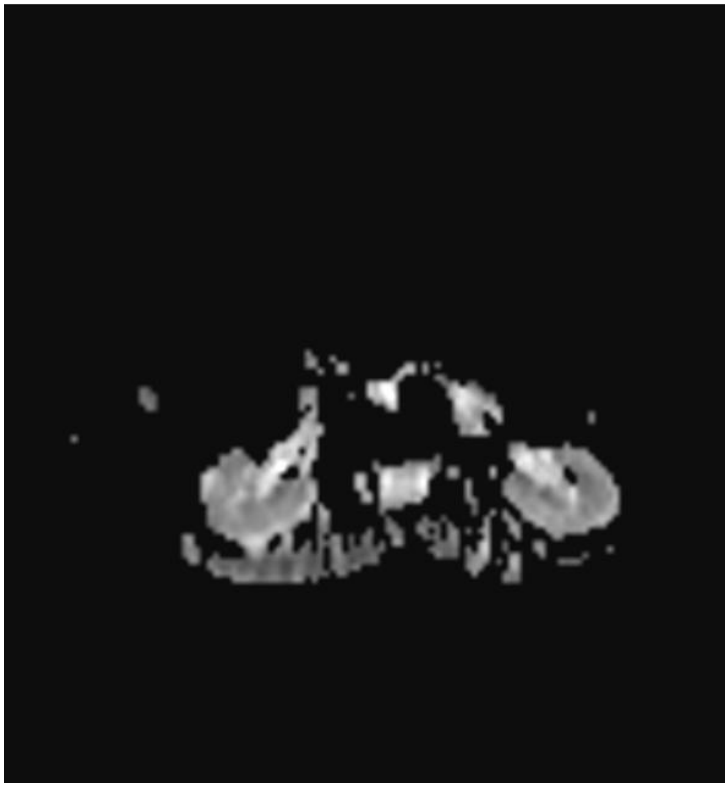


DWI &ADC

ADC: RT :2.570 x10^{-3}mm^{2}/sec LT:2.620x10^{-3}mm^{2}/sec

2.***Kuppan 48/m DWI***

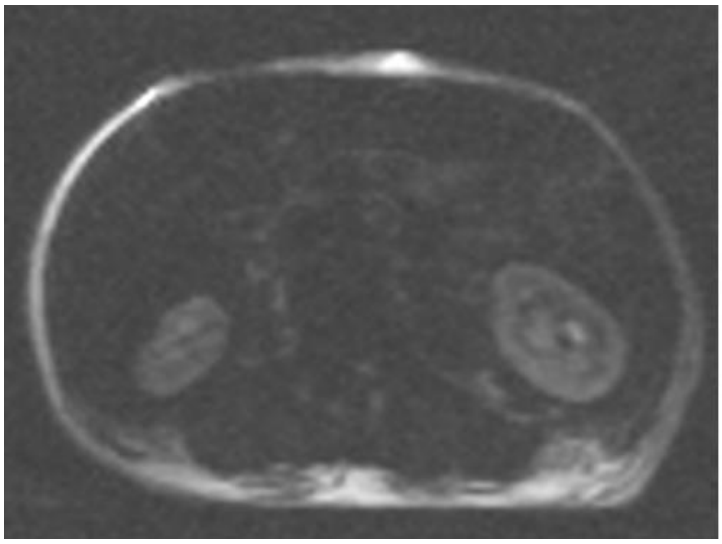




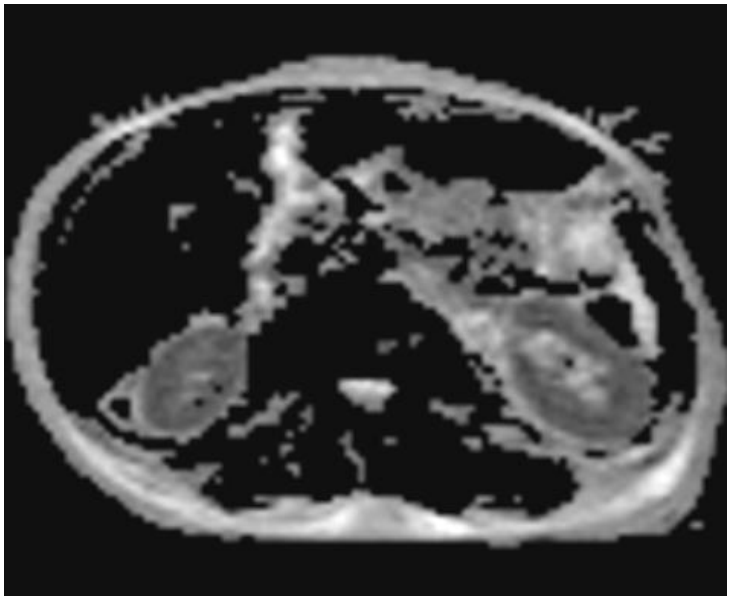
ADC : RT:2.562x10-3mm2/sec LT:2.48x10-3mm2/sec

3.KUPPUSAMY 65/M

DWI



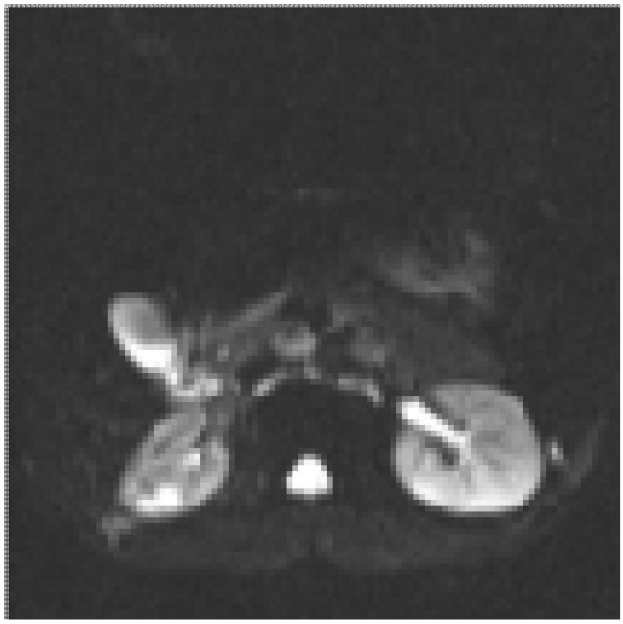
ADC

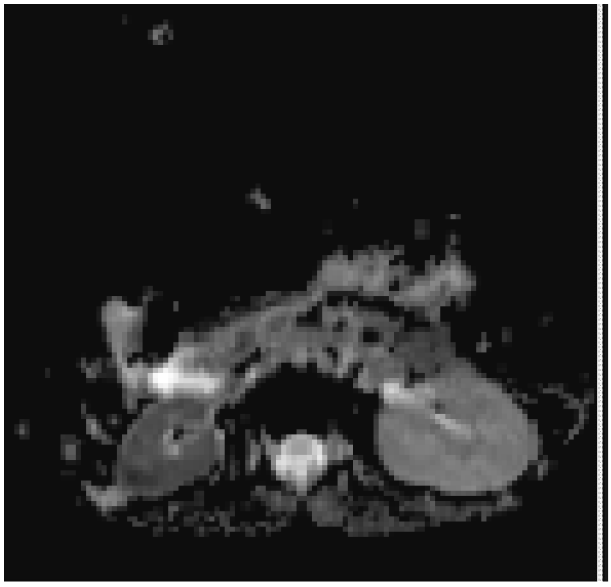


RT ADC :1370x10-3mm2/sec LT ADC : 1310x10-3mm2/sec

4.MANIKANDAN: with assymetric kidneys: A case of extra adrenal pheochromocytoma, right kidney shows **Low ADC** level.

DWI





ADC: RT:1.530 X$10^{-3}$$mm^2$/sec LT: 2.420X$10^{-3}$$mm^2$/sec

Resistive Index:

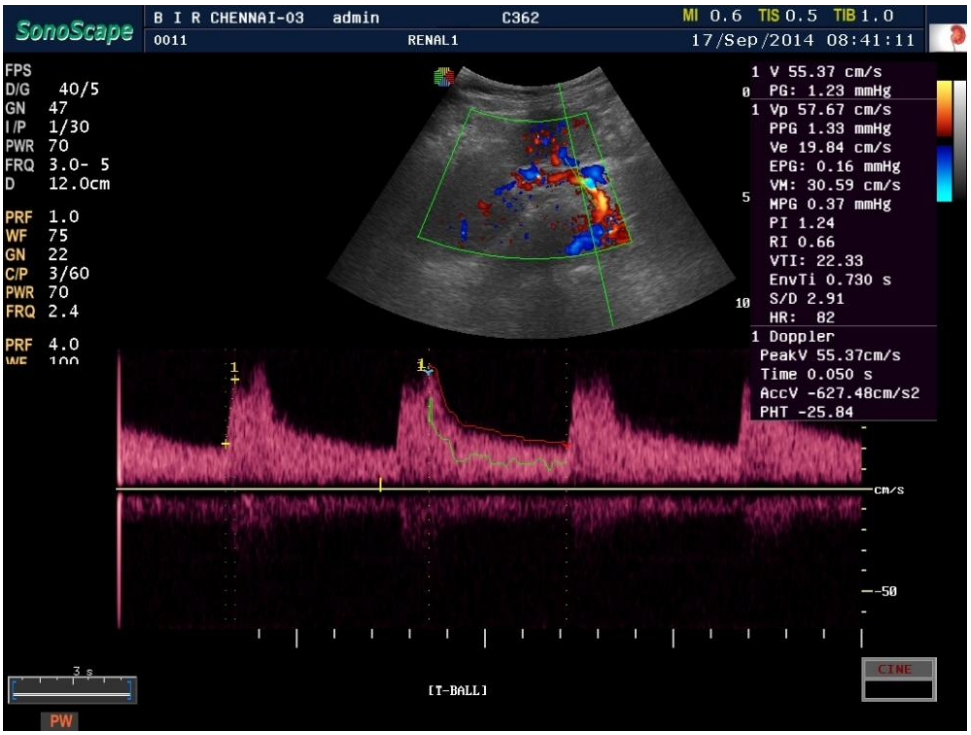
All the patients who underwent DWI were subjected for renal Doppler examination.

Duplex Doppler study done patient in supine or postero lateral position.

Renal resistive index of were measured in the intra renal arteries for each kidney separately .

Measured RI values were compared with the serum creatinine and blood urea.

RI: 0.61


SonoScape
B I R CHENNAI-03 admin C362
MI 0.6 TIS 0.5 TIB 1.0
0011 RENAL1
17/Sep/2014 08:41:11
FPS
D/G 40/5
GN 47
I/P 1/30
PWR 70
FRQ 3.0- 5
D 12.0cm
PRF 1.0
WF 75
GN 22
C/P 3/60
PWR 70
FRQ 2.4
PRF 4.0
1 V 55.37 cm/s
PG: 1.23 mmHg
1 Vp 57.67 cm/s
PPG 1.33 mmHg
Ve 19.84 cm/s
EPG: 0.16 mmHg
VM: 30.59 cm/s
MPG 0.37 mmHg
PI 1.24
RI 0.66
VTI: 22.33
EnvTi 0.730 s
S/D 2.91
HR: 82
1 Doppler
PeakV 55.37cm/s
Time 0.050 s
AccV -627.48cm/s2
PHT -25.84
cm/s
-50
3 s
[T-BALL]
CINE
PW

RI:0.66

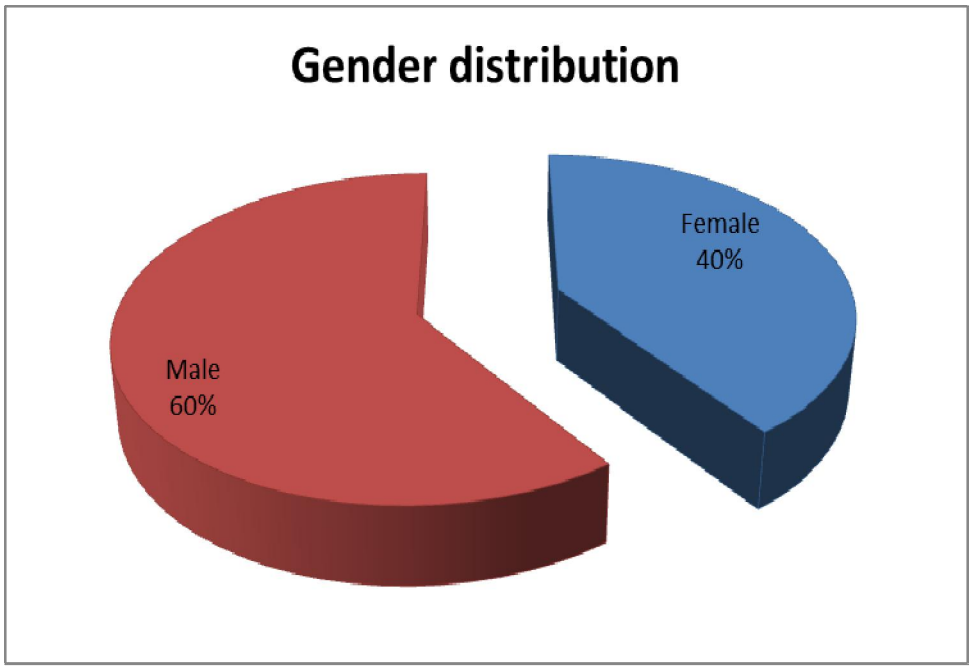

SonoScape
B I R CHENNAI-03 admin C362
MI 0.4 TIS 0.4 TIB 0.7
0011 RENAL1
17/Sep/2014 08:47:03
FPS
D/G 40/5
GN 47
I/P 1/30
PWR 70
FRQ 3.0- 5
D 12.0cm
PRF 1.0
WF 75
GN 22
C/P 3/60
PWR 70
FRQ 2.4
PRF 4.0
1 Vp 28.61 cm/s
PPG 0.33 mmHg
Ve 10.61 cm/s
EPG: 0.05 mmHg
VM: 18.51 cm/s
MPG 0.14 mmHg
PI 0.97
RI 0.63
VTI: 12.58
EnvTi 0.680 s
S/D 2.70
HR: 88
2 Doppler
PeakV 28.61cm/s
Time 0.035 s
AccV -435.02cm/s2
PHT -19.26
cm/s
-50
Save IMAGE
6 s
[T-BALL]
CINE
PW

RI:O.63

ANALYSIS:

Patient characteristics:

The population of our study 100 patients (men, women, mean age 39.5 years), 40 female, 60 male patients.

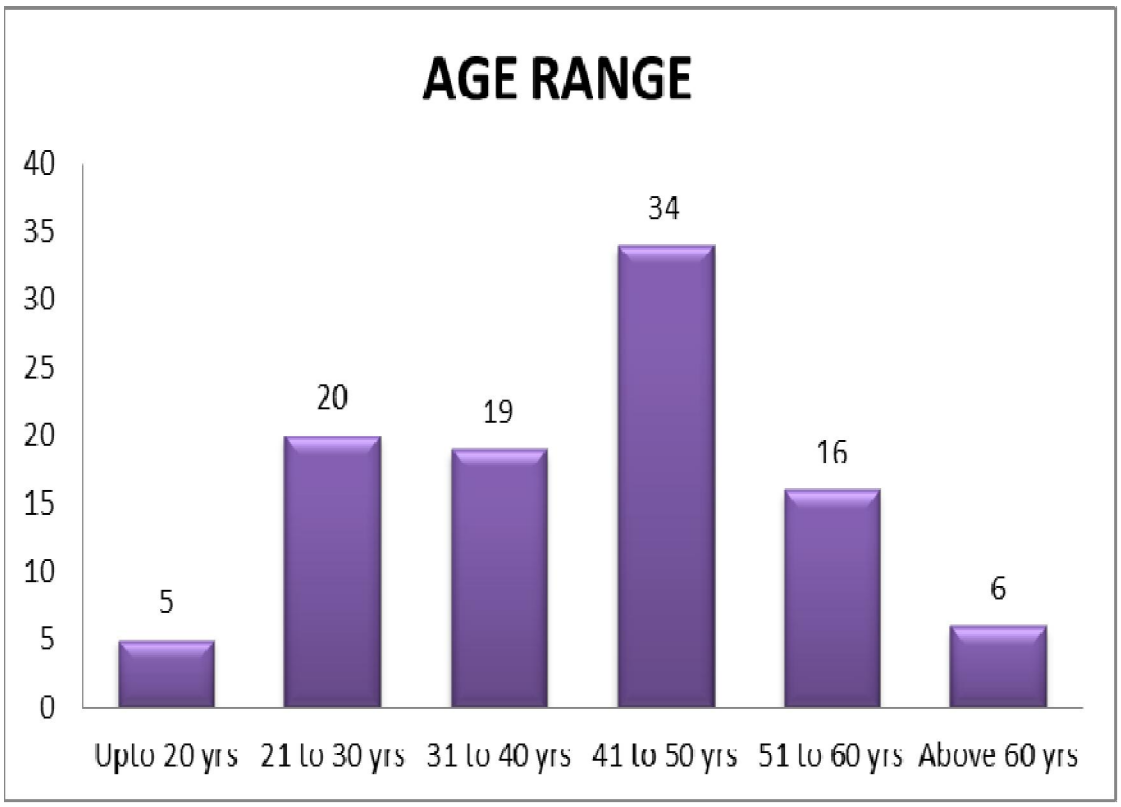


26 patient had DM , 30 patient present with hypertension, 4 had calculus disease, and 40 had no obvious background clinical

According to KDOQI -CKD classification using C-G method GFR calculated 25 patients normal , 26 patients in stage -2, 20patients had stage-3,10 had stage-4, and 19 had stage-5 disease.

Age range:

Population of our study is mixed age distribution with mean age of 40.41 years.

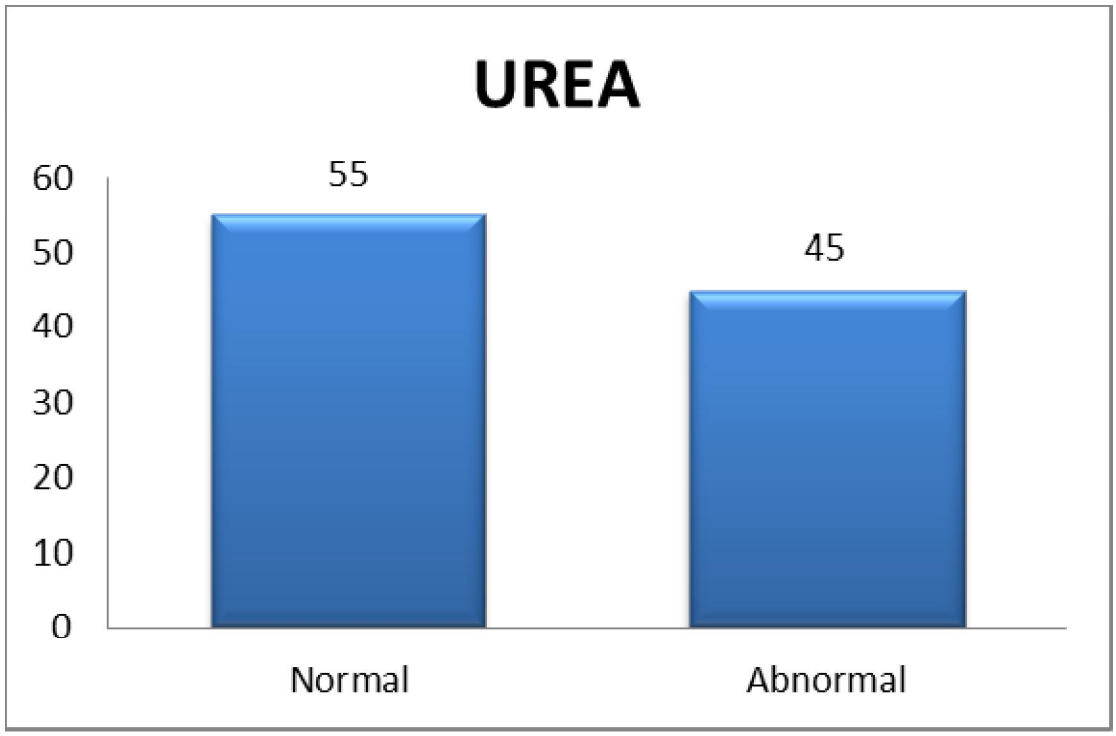


Mixed age distribution of population with maximum 41-50 year group'.

Age group representing all the age groups except under 10 year.

Blood urea:

55 patients had normal blood urea level and 55 patients had elevated blood urea level. Blood Urea >40 mg/dl considered as elevated < 40 mg/dl considered as normal.

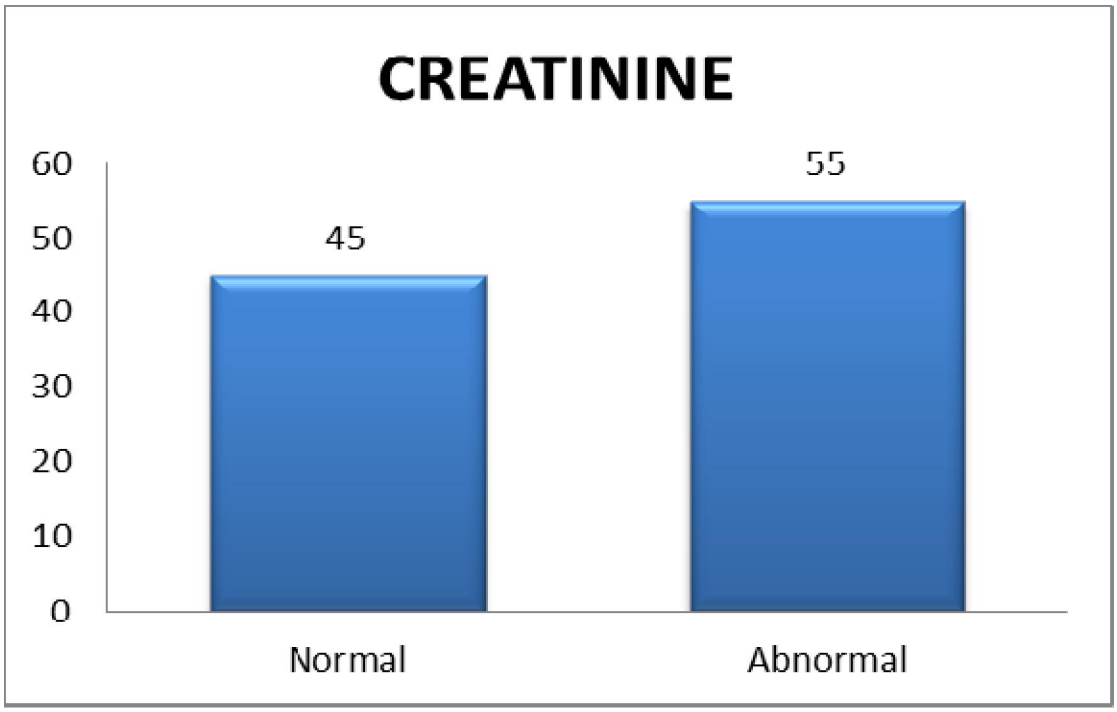


Mean urea level: 58.4 mg/dl

Serum creatinine:

55 had raised elevated serum creatinine(>1.5mg/dl) , 45 patients are normal creatinine values.

Creatinine level up to 1.4 mg/dl taken as normal above which is taken as elevated .



Mean creatinine level: 3.7mg/dl

Data analysis:

The collected data was analysed with SPSS 16.0 version.

To describe about the data descriptive statistics frequency analysis, percentage analysis were used for categorical variables and for continuous variables the mean and S.D were used.

To find the significance difference between the bivariate samples in Independent groups (Normal & Abnormal) Independent t-test was used.

For the multivariate analysis the one way ANOVA with Tukey's Post-Hoc test was used.

To assess the relationship between the variables Pearson's Correlation was used ROC-Receiver operating characteristic curves were drawn to calculate area under the curve (AUC) to differentiate the two groups and cut off ADC values were calculated so as to achieve the highest average sensitivity and specificity.

To find the significance in categorical data Chi-Square test was used. In all the above statistical tools the probability value .05 is considered as significant level.

Collected data:

All the data's collected from the patients mean, standard deviation of each variety has been calculated.

	N		Mean	Standard Deviation
	Valid	Missing		
Age	100	0	41.37	12.659
Urea	100	0	58.49	32.659
Creatinine	100	0	3.702	7.6396
ADCrt	100	0	2.2147	.379
ADClt	100	0	2.195	375
ADC	100	0	2.2051	.368
RIrt	100	0	0.6377	.05154
RIlt	100	0	0.6355	.05143

Patient characteristics:

Descriptive Statistics:

Female patients:

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Age	40	19	62	38.03	11.683
Valid N (listwise)	40				

a. Sex = F

Male patients:

Descriptive Statistics[a]

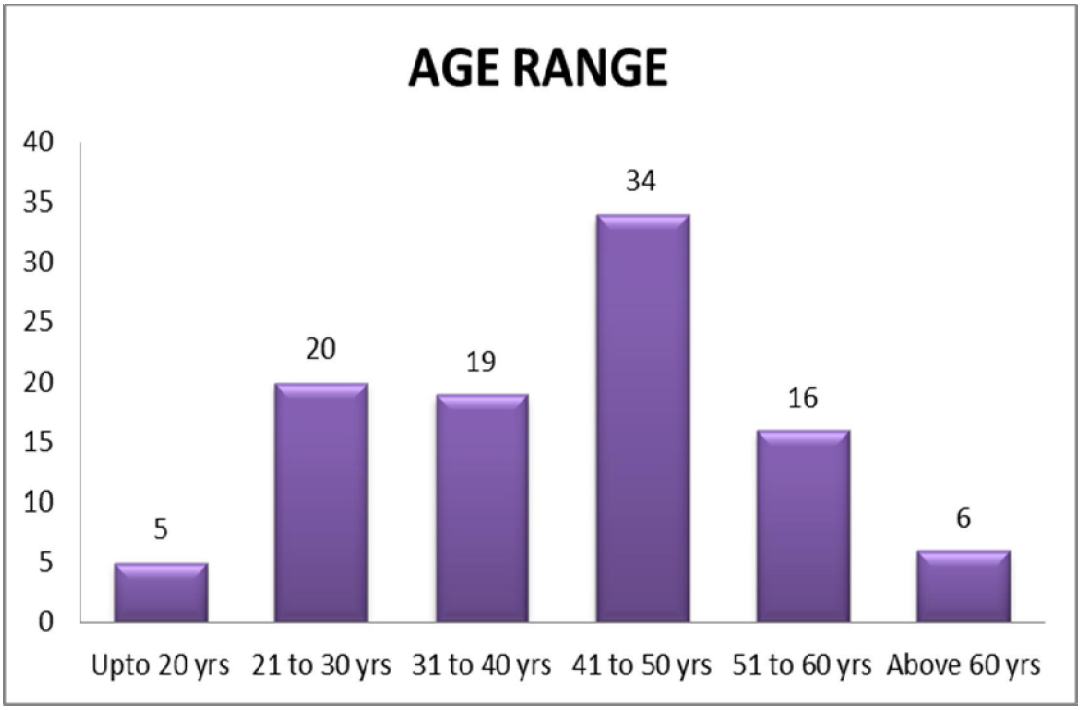
	N	Minimum	Maximum	Mean	Std. Deviation
Age	60	14	67	43.60	12.886
Valid N (listwise)	60				

Sex

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Female	40	40.0	40.0	40.0
	Male	60	60.0	60.0	100.0
	Total	**100**	**100.0**	**100.0**	

Both male and female population are equally distributed with varying age distribution.

Age distribution:



Patient had equally distributed age groups:

AGERANGE

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Upto 20 yrs	5	5.0	5.0	5.0
	21 to 30 yrs	20	20.0	20.0	25.0
	31 to 40 yrs	19	19.0	19.0	44.0
	41 to 50 yrs	34	34.0	34.0	78.0
	51 to 60 yrs	16	16.0	16.0	94.0
	Above 60 yrs	6	6.0	6.0	100.0
	Total	100	100.0	100.0	

Creatinine values:

Out of 100 patients 45 patients had normal creatinine and 55 had abnormal creatinine with mean creatinine 3.5mg/dl

CREATININERANGE

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Normal	45	45.0	45.0	45.0
	Abnormal	55	55.0	55.0	100.0
	Total	100	100.0	100.0	

Creatinine level up to 1.4 mg./dl considered as normal above 1.5 mg/dl considered as abnormal.

Blood urea :

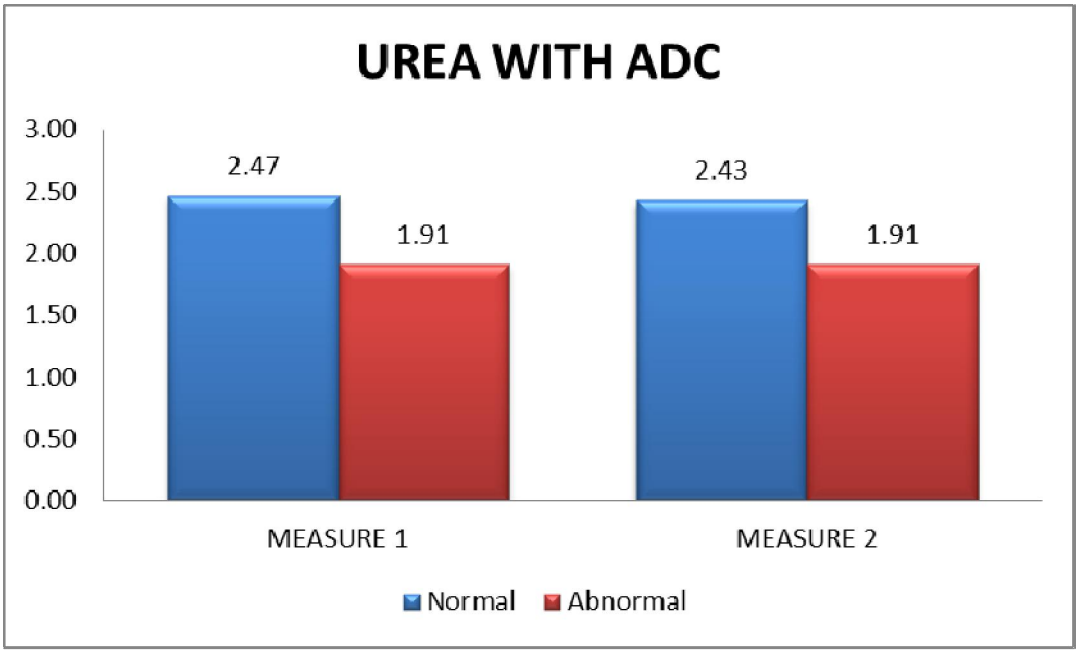
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Normal	55	55.0	55.0	55.0
	Abnormal	45	45.0	45.0	100.0
	Total	100	100.0	100.0	

Blood urea level up to 40 mg/dl considered as normal above which abnormal.

Comparisons

Blood urea VS ADC :

	ADCX10^{-3}mm^2/SEC	
	RT KIDNEY	LT KIDNEY
Normal	2.466	2.431
Abnormal	1.907	1.9078



When Comparing the ADC with blood Urea , ADC values more than 2.466 x10-^{3}mm^2/sec on right side , 2.431x10-^{3}mm^2/sec seen on left side seen only in patients with normal blood urea level. ADC below 1.907 x10-^{3}mm^2/sec on right side, 1.907 x10^{-3}mm^2/sec on left side seen only with elevated urea level.

T-test is used to find out significance between the normal and abnormal groups.

T-TEST

Group Statistics

UREARANGE		N	Mean	Std. Deviation	Std. Error Mean
ADCRt	Normal	55	2.46645	.194321	.026202
	Abnormal	45	1.90700	.319368	.047609
ADCLt	Normal	55	2.43109	.226254	.030508
	Abnormal	45	1.90789	.316833	.047231

With normal Blood Urea show a high mean ADC (with level more than $2.466x10^{-3}mm^2/sec$ on Right side , $2.431x10^{-3}mm^2/sec$ on left side), compared with raised Urea level show low ADC value with level ($< 1.907x10^{-3}mm^2/sec$ on right side, $1.907x10^{-3}mm^2/sec$ on the left side seen).

INDEPENDENT SAMPLES TEST

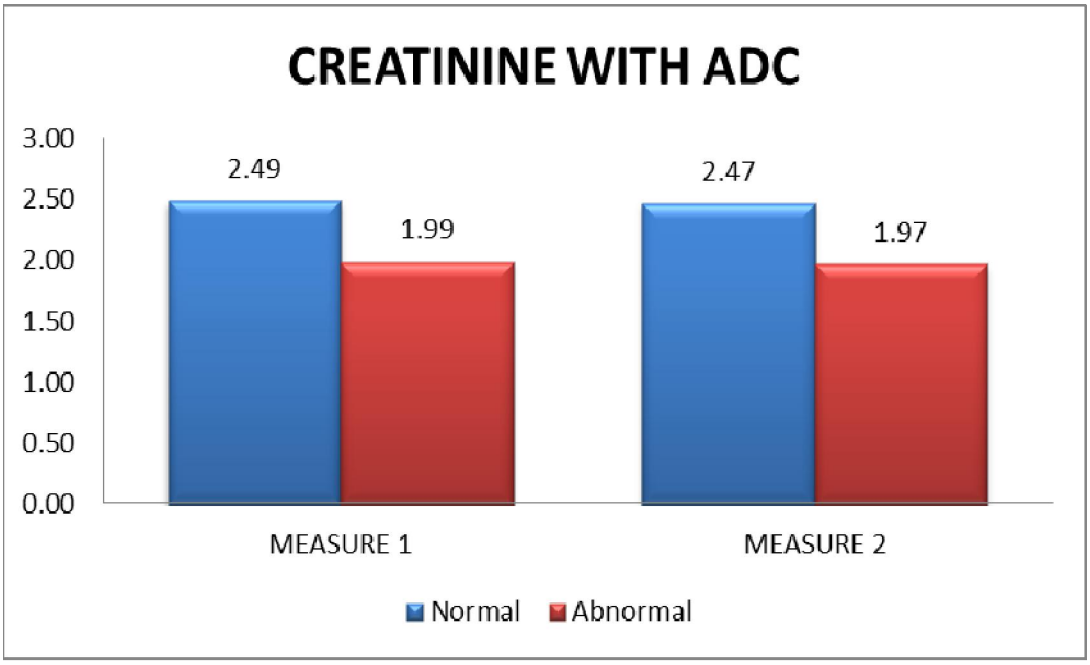
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
ADCRt	Equal variances assumed	8.562	.004	10.785	98	.000	.559455	.051874	.456512	.662398
	Equal variances not assumed			10.295	69.497	.000	.559455	.054343	.451058	.667852
ADCLt	Equal variances assumed	10.437	.002	9.616	98	.000	.523202	.054412	.415223	.631182
	Equal variances not assumed			9.305	77.398	.000	.523202	.056227	.411249	.635155

ADC values more than 2.466 $x10^{-3}mm^2$/sec on right side, $2.431x10^{-3}mm^2$/sec seen on left side seen only in patients with normal blood urea level and ADC below 1.907 $x10^{-3}mm^2$/sec on right side, 1.907 $x10^{-3}mm^2$/sec on left side seen only with elevated urea level.

Which is significant at 0.004 on right side , 0.002 on left side.

SERUM CREATINE WITH ADC:

	ADC $x10^{-3}mm^2/sec$	
CREATININE	RT	LEFT
NORMAL	2.49	2.47
ABNORMAL	1.99	1.97



T-test is used to find out significance between the normal and abnormal groups.

Comparison of serum creatinine level with the ADC level:

T-Test

Group Statistics

CREATININERANGE		N	Mean	Standard. Deviation	Standard. Error Mean
ADCRt	Normal	45	2.49318	.180027	.026837
	Abnormal	55	1.98685	.347007	.046790
ADCLt	Normal	45	2.47062	.184660	.027527
	Abnormal	55	1.97067	.340741	.045946

With normal serum creatinine show a high mean ADC (with level more than $2.493x10^{-3}mm^2/sec$ on Right side, $2.470x 10^{-3}mm^2/sec$ on left side), compared with raised creatinine level show low ADC value with level (< $1.986 x10^{-3}mm^2/sec$ on right side, $1.970x 10^{-3}mm^2/sec$ on the left side seen).

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
ADCRt	Equal variances assumed	16.771	.000	8.856	98	.000	.506323	.057173	.392865	.619781
	Equal variances not assumed			9.387	84.190	.000	.506323	.053940	.399060	.613586
ADCLt	Equal variances assumed	25.651	.000	8.833	98	.000	.499949	.056599	.387630	.612269
	Equal variances not assumed			9.334	86.109	.000	.499949	.053561	.393476	.606423

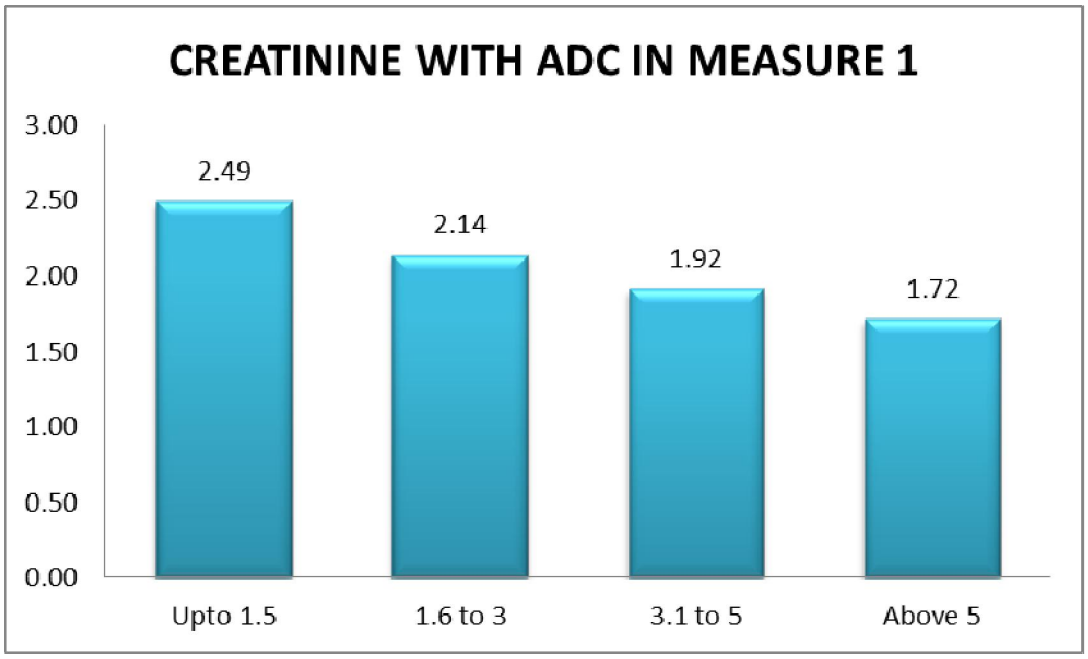
Patient with low serum creatinine show a high mean ADC with level more than $2.493x10^{-3}mm^2/sec$ on right side $2.470x10^{-3}mm^2/sec$ on left side. Compared with raised creatinine level show low ADC value $<1.986\ x10^{-3}mm^2/sec$ on right side, $1.970x10^{-3}mm^2/sec$ on the left side seen which is significant at .000 (<0.05) on both sides.

ADC values with different range of creatinine level:

CREATININE mg/dl	**ADC RT** $AX10^{-3}mm^2/sec$	**CREATININE**	**ADC LT** $AX10^{-3}mm^2/sec$
UPTO1.5	2.49	UPTO1.5	2.47
1.6-3.0	2.14	1.6-3.0	2.14
3.1-5	1.92	3.1-5	1.88
ABOVE 5	1.72	ABOVE 5	1.70

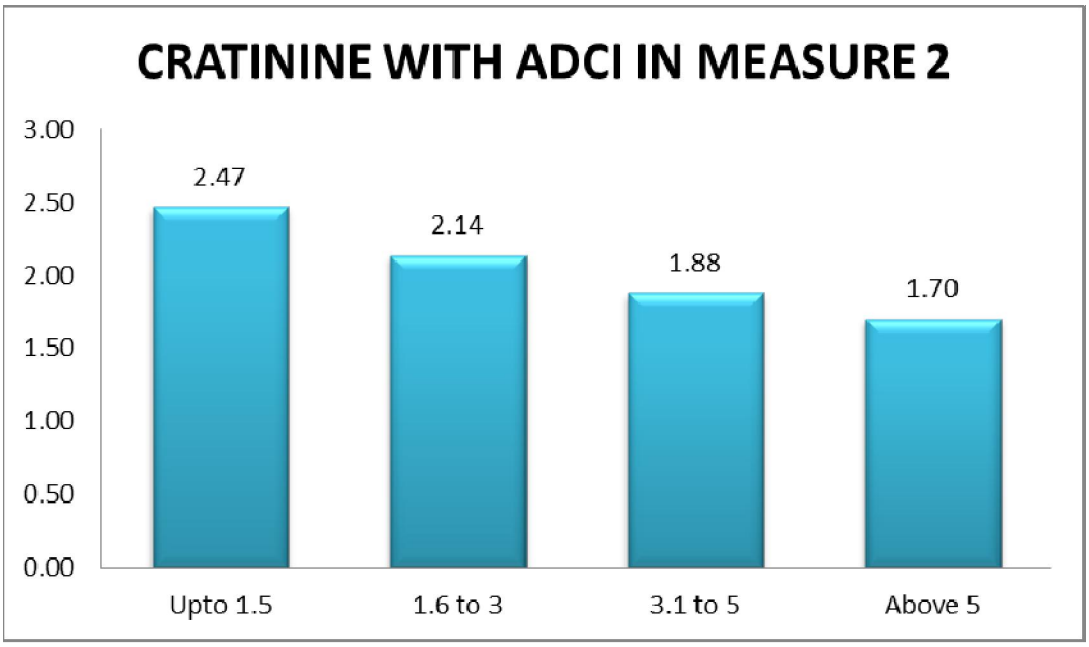
ADC values above $2.4x10^{-3}mm^2/sec$ seen with normal creatinine level only.

ADC values below$1.72x10^{-3}mm^2/sec$ seen with creatinine> 5mg/dl only.



ADC VALUES FOR DIFFERENT CREATININE LEVEL

RIGHT KIDNEY



ADC VALUES FOR DIFFERENT CREATININE LEVEL

LEFT KIDNEY

CORRELATIONS:

		Urea	Creatinine	ADCRt	ADCLt
Urea	Pearson Correlation	1	.509**	-.754**	-.744**
	Sig. (2-tailed)		.000	.000	.000
	N	100	100	100	100
Creatinine	Pearson Correlation	.509**	1	-.401**	-.461**
	Sig. (2-tailed)	.000		.000	.000
	N	100	100	100	100
ADCRt	Pearson Correlation	-.754**	-.401**	1	.905**
	Sig. (2-tailed)	.000	.000		.000
	N	100	100	100	100
ADCLt	Pearson Correlation	-.744**	-.461**	.905**	1
	Sig. (2-tailed)	.000	.000	.000	
	N	100	100	100	100

Correlating the ADC values with creatinine level there is significant inverse correlation (with **p value of <0.05**).Correlating the ADC values with the urea level there is significant inverse correlation (**with p value of <0.05)**

ONE WAY CORRELATION:

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
ADCRt	Upto 1.5	49	2.49408	.174329	.024904	2.44401	2.54415	2.171	3.280
	1.6 to 3	23	2.13952	.146524	.030552	2.07616	2.20288	1.912	2.522
	3.1 to 5	10	1.91610	.327951	.103707	1.68150	2.15070	1.621	2.781
	Above 5	18	1.71611	.347549	.081918	1.54328	1.88894	1.141	2.672
	Total	100	2.21470	.379705	.037970	2.13936	2.29004	1.141	3.280
ADCLt	Upto 1.5	49	2.46824	.177579	.025368	2.41724	2.51925	2.021	3.260
	1.6 to 3	23	2.13635	.181975	.037944	2.05766	2.21504	1.538	2.404
	3.1 to 5	10	1.87960	.343220	.108536	1.63408	2.12512	1.621	2.802
	Above 5	18	1.70494	.306668	.072282	1.55244	1.85745	1.311	2.680
	Total	100	2.19565	.375463	.037546	2.12115	2.27015	1.311	3.260

ADC Value above on right 2.494 $x10^{-3}mm^2/sec$, on left 2.468 x $10^{-3}mm^2/sec$ seen only who had normal renal function, and below on right side 1.716 x $10^{-3}mm^2/sec$, on left side $1.704x10^{-3}mm^2/sec$ seen only with impaired renal function.

ANOVA:

ANOVA						
		Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
ADCRt	Between Groups	9.321	3	3.107	60.226	.000
	Within Groups	4.952	96	.052		
	Total	14.273	99			
ADCLt	Between Groups	9.055	3	3.018	59.122	.000
	Within Groups	4.901	96	.051		
	Total	13.956	99			

ANOVA for between groups gives F value of 60.226 for right side, F value of 59.12 on left side which is statistically significant at 0.000(< 0.05) level.

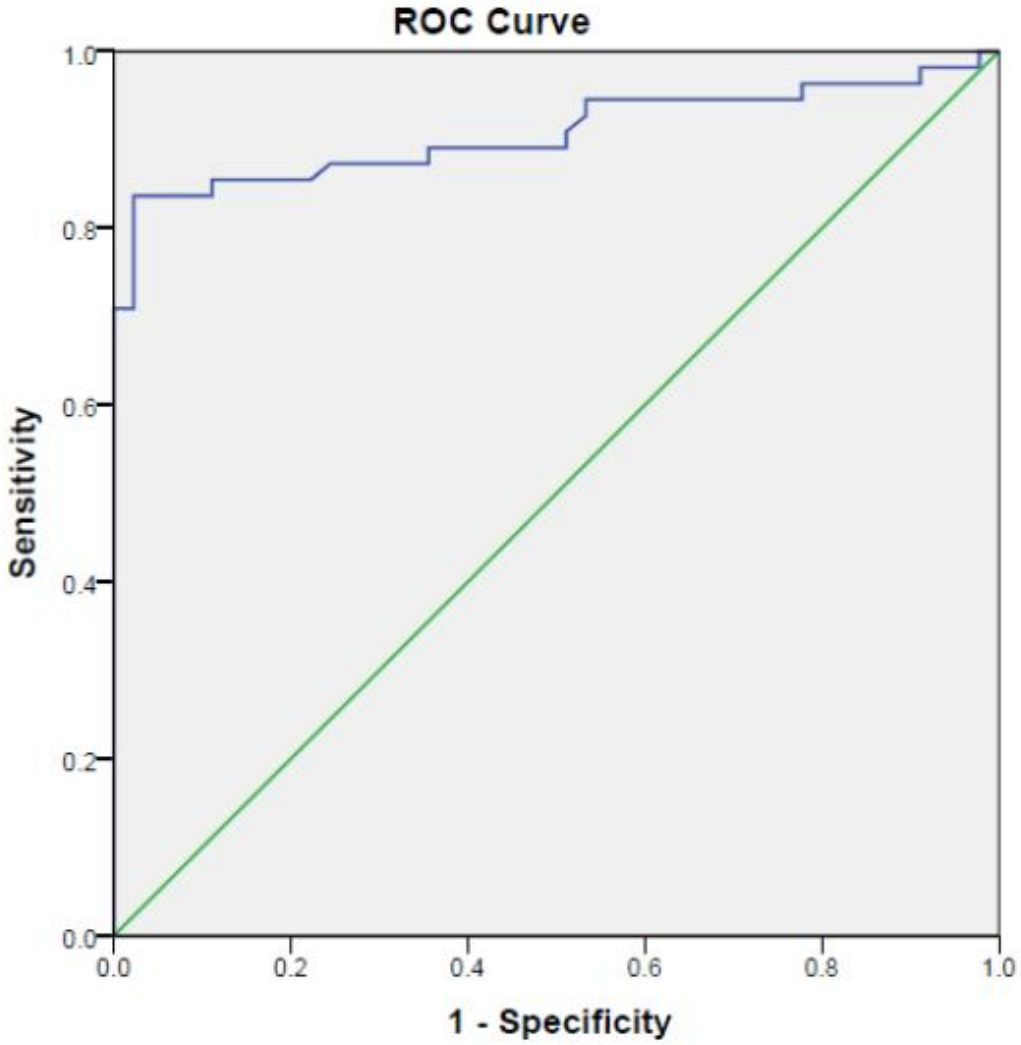
For analysis within groups post hoc test-multiple tests done.

Multiple Comparisons							
Tukey HSD							
Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
ADCRt	Upto 1.5	1.6 to 3	.354560*	.057409	.000	.20446	.50466
		3.1 to 5	.577982*	.078814	.000	.37191	.78405
		Above 5	.777971*	.062601	.000	.61429	.94165
	1.6 to 3	Upto 1.5	-.354560*	.057409	.000	-.50466	-.20446
		3.1 to 5	.223422	.086034	.052	-.00152	.44837
		Above 5	.423411*	.071477	.000	.23653	.61030
	3.1 to 5	Upto 1.5	-.577982*	.078814	.000	-.78405	-.37191
		1.6 to 3	-.223422	.086034	.052	-.44837	.00152
		Above 5	.199989	.089582	.122	-.03423	.43421
	Above 5	Upto 1.5	-.777971*	.062601	.000	-.94165	-.61429
		1.6 to 3	-.423411*	.071477	.000	-.61030	-.23653
		3.1 to 5	-.199989	.089582	.122	-.43421	.03423
ADCLt	Upto1.5	1.6 to 3	.331897*	.057111	.000	.18257	.48122
		3.1 to 5	.588645*	.078405	.000	.38365	.79364
		Above 5	.763300*	.062275	.000	.60047	.92613
	1.6 to 3	Upto 1.5	-.331897*	.057111	.000	-.48122	-.18257
		3.1 to 5	.256748*	.085587	.018	.03297	.48052
		Above 5	.431403*	.071106	.000	.24549	.61732
	3.1 to 5	Upto 1.5	-.588645*	.078405	.000	-.79364	-.38365
		1.6 to 3	-.256748*	.085587	.018	-.48052	-.03297
		Above 5	.174656	.089116	.211	-.05835	.40766
	Above 5	Upto 1.5	-.763300*	.062275	.000	-.92613	-.60047
		1.6 to 3	-.431403*	.071106	.000	-.61732	-.24549
		3.1 to 5	-.174656	.089116	.211	-.40766	.05835
*. The mean difference is significant at the 0.05 level.							

Multiple comparisons made using post Hoc comparing creatinine group with ADC values of the right and left kidney with significance of .000 (<0.05) .

AREA UNDER THE CURVE:

ADC RIGHT SIDE



Diagonal segments are produced by ties.

Area Under the Curve				
Test Result Variable(s): ADCRt				
Area	**Std. Error[a]**	**Asymptotic Sig.[b]**	**Asymptotic 95% Confidence Interval**	
			Lower Bound	**Upper Bound**
.907	.032	.000	.844	.971
The test result variable(s): ADCRt has at least one tie between the positive actual state group and the negative actual state group. Statistics may be biased.				
a. Under the nonparametric assumption				
b. Null hypothesis: true area = 0.5				

AUC	**Sig**	**95% C.I**	
		LB	**UB**
0.907	0.0001	0.844	0.971

Coordinates of the Curve		
Test Result Variable(s): ADCRt		
Positive if Less Than or Equal To[a]	Sensitivity	1 – Specificity
.14100	0.000	0.000
1.22650	.018	0.000
1.34400	.036	0.000
1.42050	.055	0.000
1.49550	.073	0.000
1.55300	.091	0.000
1.59000	.109	0.000
1.61000	.127	0.000
1.62050	.145	0.000
1.62450	.164	0.000
1.65500	.182	0.000
1.69100	.200	0.000
1.71900	.218	0.000
1.75500	.236	0.000
1.77700	.255	0.000
1.78500	.273	0.000
1.79500	.291	0.000
1.80700	.309	0.000
1.81650	.327	0.000
1.85100	.345	0.000
1.89500	.364	0.000
1.91050	.382	0.000
1.91400	.455	0.000
1.93400	.473	0.000
1.97650	.491	0.000
2.00150	.509	0.000
2.00700	.527	0.000
2.04150	.545	0.000
2.08550	.564	0.000

Coordinates of the Curve		
Test Result Variable(s): ADCRt		
Positive if Less Than or Equal To[a]	Sensitivity	1 – Specificity
2.10500	.600	0.000
2.11500	.618	0.000
2.12350	.655	0.000
2.14450	.673	0.000
2.16500	.691	0.000
2.16950	.709	0.000
2.17150	.709	.022
2.18650	.727	.022
2.20150	.764	.022
2.20300	.782	.022
2.20500	.800	.022
2.21100	.818	.022
2.22500	.836	.022
2.24750	.836	.044
2.26150	.836	.067
2.28750	.836	.111
2.32750	.855	.111
2.34300	**.855**	**.133**
2.34450	.855	.178
2.35050	.855	.200
2.35900	.855	.222
2.36350	.873	.244
2.37350	.873	.267
2.38400	.873	.289
2.39450	.873	.311
2.40400	.873	.356
2.41550	.891	.356
2.42700	.891	.378
2.43000	.891	.400

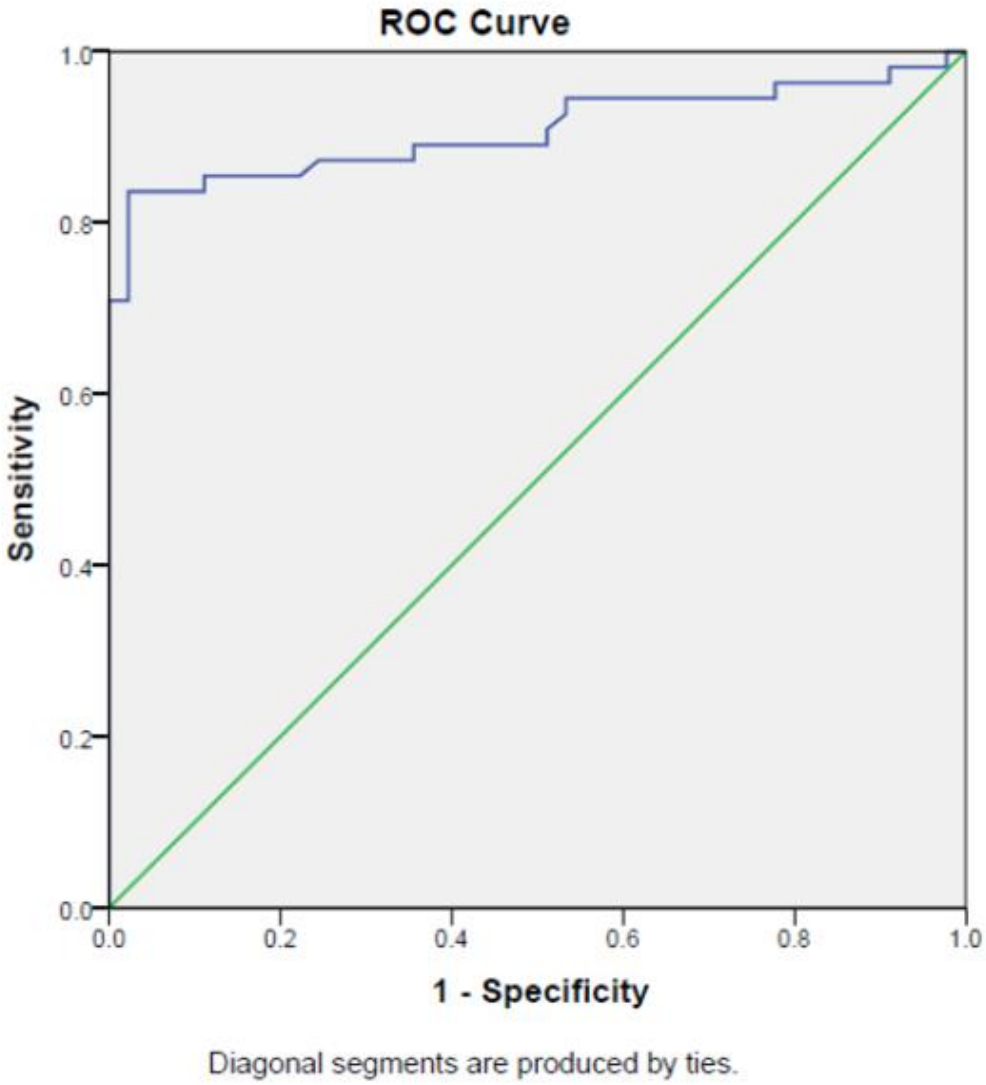
Coordinates of the Curve		
Test Result Variable(s): ADCRt		
Positive if Less Than or Equal To[a]	Sensitivity	1 – Specificity
2.44750	.891	.444
2.47250	.891	.467
2.48500	.891	.489
2.50400	.891	.511
2.52100	.909	.511
2.52300	.927	.533
2.52700	.945	.533
2.53800	.945	.556
2.55300	.945	.578
2.56050	.945	.600
2.56150	.945	.622
2.56300	.945	.689
2.56700	.945	.711
2.57700	.945	.733
2.59200	.945	.756
2.60550	.945	.778
2.61550	.964	.778
2.62100	.964	.800
2.62350	.964	.822
2.62750	.964	.844
2.63100	.964	.867
2.63700	.964	.889
2.65700	.964	.911
2.67700	.982	.911
2.73150	.982	.978
3.03050	1.000	.978
4.28000	1.000	1.000

AUC	Sig	95% C.I	
		LB	UB
0.907	0.0001	0.844	0.971

ROC analysis was performed for ADC in differentiating patients with elevated & with normal renal parameters .

To detect the renal dysfunction on right side AUC was 0.907, SE = 0.081, and P = 0.0001. on right side AUC For a cut-off ADC value of 2.343 ($\times 10^{-3}$ mm^2/s), sensitivity was 85.5%, specificity was 86.7%, and 95% confidence intervals = (0.562, 0.878) on right side, (values lower than cut-off indicated renal dysfunction).

ROC left side:



Area Under the Curve

Test Result Variable(s): ADCLt

Area	Std. Error[a]	Asymptotic Sig.[b]	Asymptotic 95% Confidence Interval	
			Lower Bound	Upper Bound
.908	.031	.000	.847	.969

The test result variable(s): ADCLt has at least one tie between the positive actual state group and the negative actual state group. Statistics may be biased.

a. Under the nonparametric assumption

b. Null hypothesis: true area = 0.5

AUC	Sig.	95 % C.I	
		LB	UB
0.908	0.0001	0.847	0.969

Test Result Variable(s): ADCLt		
Positive if Less Than or Equal To[a]	**Sensitivity**	**1 – Specificity**
.31100	0.000	0.000
1.35550	.018	0.000
1.42600	.036	0.000
1.48900	.055	0.000
1.53200	.073	0.000
1.54400	.091	0.000
1.55500	.109	0.000
1.56400	.127	0.000
1.57400	.145	0.000
1.60050	.164	0.000
1.62450	.200	0.000
1.64450	.218	0.000
1.68050	.236	0.000
1.70100	.255	0.000
1.70500	.273	0.000
1.71800	.291	0.000
1.75500	.309	0.000
1.79050	.327	0.000
1.79950	.345	0.000
1.80450	.382	0.000
1.81050	.400	0.000
1.85650	.418	0.000
1.90500	.436	0.000
1.91050	.455	0.000
1.91900	.473	0.000
1.94350	.491	0.000
1.99000	.509	0.000
2.02000	.527	0.000
2.04700	.527	.022
2.08550	.545	.022
2.09900	.564	.022
2.10150	.582	.022
2.11150	.600	.022
2.12250	.636	.022
2.14050	.655	.022
2.15800	.673	.022
2.16100	.691	.022

Test Result Variable(s): ADCLt		
Positive if Less Than or Equal To[a]	**Sensitivity**	**1 – Specificity**
2.16600	.709	.022
2.17050	.727	.022
2.17250	.745	.022
2.17900	.764	.022
2.19200	.764	.044
2.20200	.782	.044
2.20700	.782	.067
2.22050	.800	.067
2.23750	.818	.067
2.26350	.818	.089
2.29350	.818	.111
2.30700	.836	.111
2.32650	**.836**	**.156**
2.35150	.836	.178
2.36100	.836	.222
2.36700	.836	.267
2.38250	.855	.267
2.39650	.873	.267
2.40100	.873	.289
2.40250	.909	.311
2.40350	.909	.333
2.41200	.927	.333
2.42100	.927	.356
2.42500	.927	.400
2.43750	.927	.422
2.44850	.927	.444
2.45050	.927	.467
2.45350	.945	.467
2.45800	.945	.489
2.46100	.945	.533
2.46350	.945	.578
2.47250	.945	.600
2.49450	.945	.622
2.51450	.945	.644
2.52550	.964	.644
2.54550	.964	.667
2.56050	.964	.689

Test Result Variable(s): ADCLt		
Positive if Less Than or Equal To[a]	**Sensitivity**	**1 – Specificity**
2.56150	.964	.711
2.56550	.964	.756
2.58050	.964	.778
2.60050	.964	.822
2.61450	.964	.844
2.62100	.964	.889
2.65100	.964	.933
2.69050	.982	.933
2.70250	.982	.956
2.75300	.982	.978
3.03100	1.000	.978
4.26000	1.000	1.000

The test result variable(s): ADCLt has at least one tie between the positive actual state group and the negative actual state group.

a. The smallest cutoff value is the minimum observed test value minus 1, and the largest cutoff value is the maximum observed test value plus 1. All the other cutoff values are the averages of two consecutive ordered observed test values.

For a cut-off ADC value of 2.326 ($\times 10^{-3}$ mm^2/s), sensitivity was 83.6%, specificity was 84.7%, and 95% confidence intervals = (0.562, 0.878) for left side (values below cut-off indicated renal dysfunction).

Average ADC VALUE FOR BOTH SIDE: 2.334 $\times 10^{-3}$ mm^2/s.

Values of ADC below this cut off will indicate renal dysfunction.

ADCRt

Tukey HSD

CREAT	N	Subset for alpha = 0.05			
		1	2	3	4
Above 5	18	1.71611			
3.1 to 5	10		1.91610		
1.6 to 3	23			2.13952	
Upto 1.5	49				2.49408
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 18.228.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

ADCLt

Tukey HSD

CREAT	N	Subset for alpha = 0.05		
		1	2	3
Above 5	18	1.70494		
3.1 to 5	10	1.87960		
1.6 to 3	23		2.13635	
Upto 1.5	49			2.46824
Sig.		.098	1.000	1.000

Means for groups in homogeneous subsets are displayed.

Apparent Diffusion Co-efficient values and Renal function:

The mean ADC value of the renal parenchyma in patients with elevated serum markers is significantly lower than in patients with normal renal parameters compared on both kidneys.

Patient with normal sr.creatinine

55 patients	ADC (mean)	SD
RT	2.49318	.180027
Lt	2.47062	.184660

Patient with eleavated sr.creatinine

45 patients	ADC (mean)	SD
Rt	1.98685	.347007
Lt	1.97067	.340741

Both sides show reduced values in ADC except two patients who had asymmetrical kidneys. Kidney on the normal side shows ADC value above 2.493×10^{-3} mm^2/s (RT),2.470×10^{-3} mm^2/s(LT)

We have not selected the patients as acute and chronic kidney disease as separate entity. There is no major difference among the ADC values in chronic renal dysfunction and with acute renal dysfunction.

Apparent Diffusion Coefficient values Vs Serum markers (Blood Urea &Serum Creatinine):

		Urea	Creatinine	ADCRt	ADCLt
Urea	Pearson Correlation	1	.509**	-.754**	-.744**
	Sig. (2-tailed)		.000	.000	.000
	N	100	100	100	100
Creatinine	Pearson Correlation	.509**	1	-.401**	-.461**
	Sig. (2-tailed)	.000		.000	.000
	N	100	100	100	100
ADC Right	Pearson Correlation	-.754**	-.401**	1	.905**
	Sig. (2-tailed)	.000	.000		.000
	N	100	100	100	100
ADC Left	Pearson Correlation	-.744**	-.461**	.905**	1
	Sig. (2-tailed)	.000	.000	.000	
	N	100	100	100	100

The ADC values of renal parenchyma and Sr.Creatinine levels shown a inverse correlation (Pearson's correlation coefficient R = – 0.401(RT), -461(LT) ; P = 0.000).

The ADC values of renal parenchyma and blood urea levels shown an inverse correlation **(Pearson's correlation coefficient R = – 0.754(right),-0.744(left) ; P = 0.000**).

Patients with elevated serum creatinine had low ADC values compared to the patients with normal serum creatinine value had high ADC values. Persistent low level of ADC values seen with high creatinine& urea level only.

ADC values vs Glomerular Filtration Rate :

Test results shown a positive correlation (ADCα GFR) between the ADC values and the measured GFR.

Patient with normal GFR had high level of ADC. Patient with decreased GFR had low ADC values compared to the normal patients.

ADC &GFR

	Mean	Std.deviation	N
ADC RT	2.214	.379705	100
GFR	59.19	35.9359	100

	Mean	Std.deviation	N
ADC LT	2.195	.375463	100
GFR	59.19	35.9359	100

CORRELATIONS :ADC WITH GFR

		ADC RT	GFR
ADC RT	Pearson Correlation	1	.296**
	Sig. (2-tailed)		0.003
	N	100	100
GFR	Pearson Correlation	.296**	1
	Sig. (2-tailed)	0.003	100
	N	100	

**. Correlation is significant at the 0.01 level (2-tailed).

		ADC LT	GFR
ADC LT	Pearson Correlation	1	.312*8
	Sig. (2-tailed)		0.003
	N	100	100
GFR	Pearson Correlation	.312	1
	Sig. (2-tailed)	0.003**	100
	N	100	

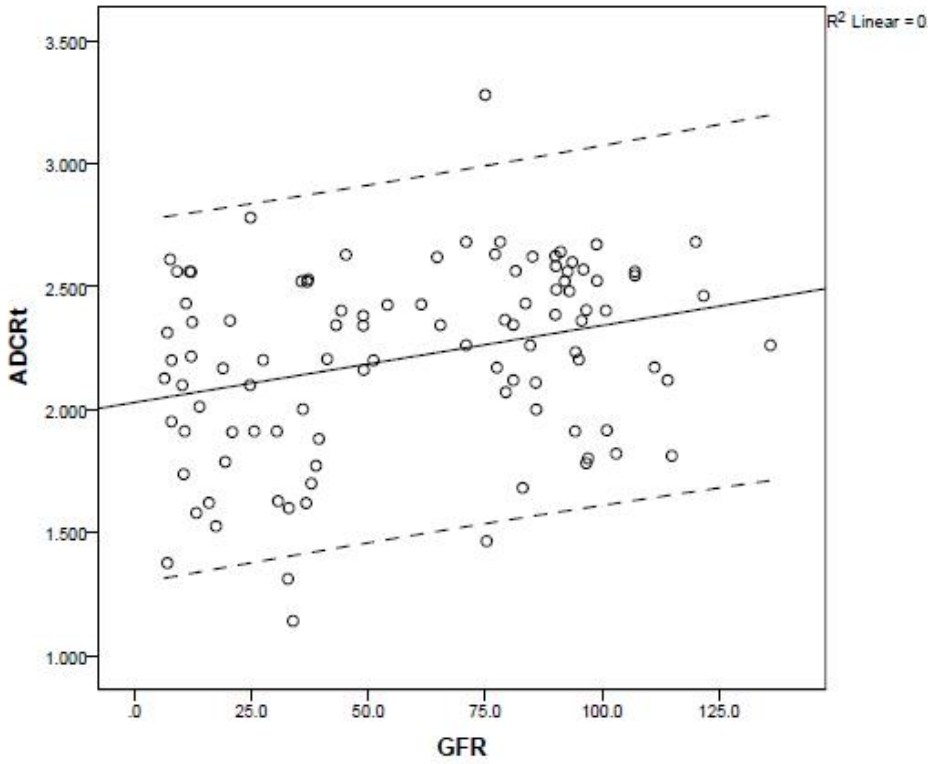
**. Correlation is significant at the 0.01 level (2-tailed).

The ADC values of renal parenchyma and GFR levels shown a linear correlation (**Pearson's correlation coefficient R = .0.296**) for right side , The ADC values of renal parenchyma and GFR levels shown a linear correlation (**Pearson's correlation coefficient R = 0.312**) for left side which is significant at 0.003 level.

Graphics map:

Represents a positive linear correlation ADC with GFR level. High ADC level are seen only with patient with normal GFR level on both side. When GFR falls ADC also falls . so we can predict the GFRAND stage of kidney disease with parenchymal ADC level.

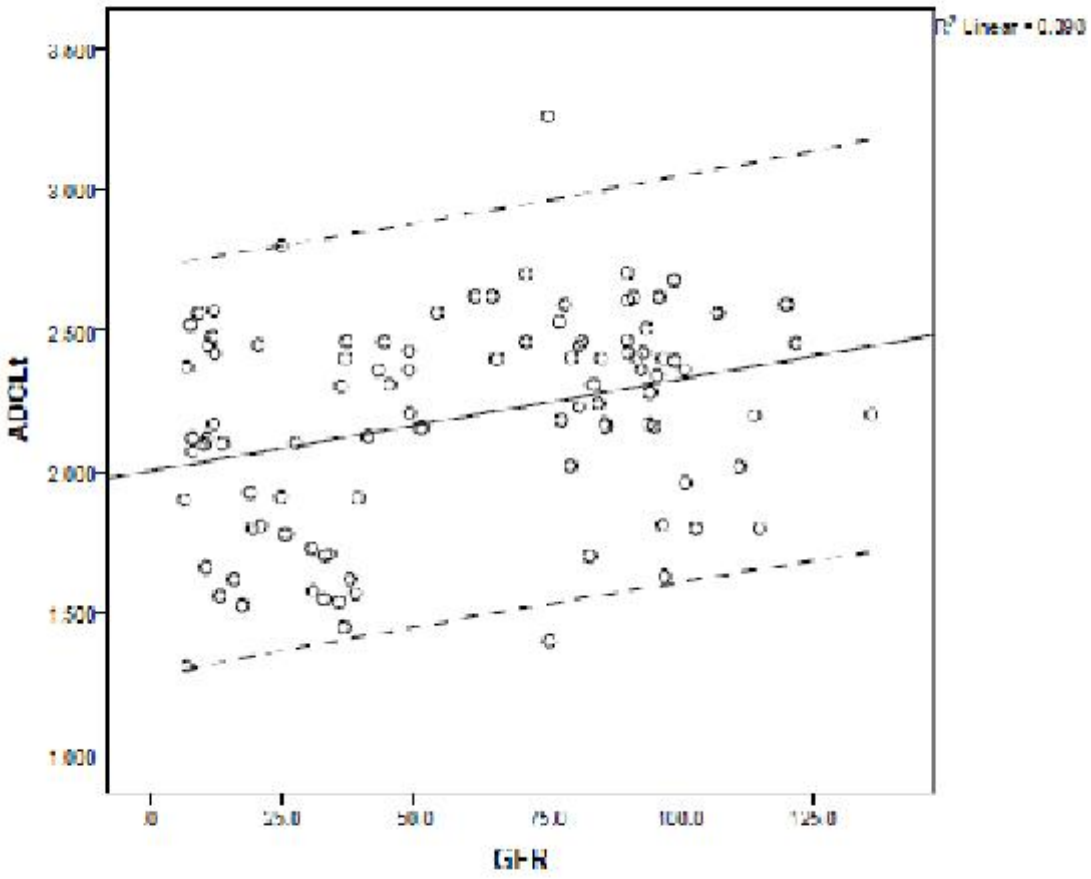
GFR vs ADC RIGHT



Graph

There is linear positive correlation between RT -ADC and GFR.

GFR vs ADC MAP LEFT SIDE:



There is linear positive correlation between LT -ADC and GFR.

ADC values and stages of CKD:

Renal parenchyma of Different stages of CKD had shown different level of mean ADC and significantly different from each other .

There was a reduced ADC values while increase in the stage of the kidney disease.

The difference between the ADC values are statistically significant between creatinine level <1.5 , 1.5-3 mg /dl. And 3.5mg/dl,. 5mg/dl.

Level of ADC is much lower in group stage 4, stage 5 ($1.716x10^{-3}$ mm^2/sec for right , $1.704x10^{-3}$ mm^2/sec for left), compared to the patients of stage1 and normal GFR ($2.494x10^{-3}$ mm^2/sec for right, $2.468x10^{-3}$ mm^2/sec for left)

Resistive Index vs Serum Creatinine/Blood urea :

RI of the kidneys were compared with the serum markers of renal function.

All the patients with the normal sr.creatinine (<1.4) have shown RI values of 0.58-.0.65. Patients with elevated serum markers shows variation in the RI value between 0.58 -0.74.

Statistics

	N		Mean	Std. Deviation
	Valid	Missing		
ADCRt	100	0	2214.70	379.705
ADCLt	100	0	2195.65	375.463
ADC	100	0	2.205175	.3684642
RIRt	100	0	.6377	.05154
RILt	100	0	.6355	.05143

RI values cannot be reliably correlated with the serum creatinine level. Measuring the RI value perfectly in patients the severely contracted kidneys and those unable to hold breath is difficult which operator dependent and needs patient co-operation. And some cases measuring RI is very difficult(obese persons, severely contracted kidneys, patients who unable to hold breath). Patients with renal dysfunction varied RI values from 0.58 to 0.78 .(p value>0.05)

Renal Resistive Index vs ADC

- RI values of all the patients normal and abnormal parameters were collected.
- Comparing the RI value with ADC values patients with normal renal parameters shown normal RI Values.
- Those with deranged renal parameters shown variable RI values and not correlating with the elevated renal parameters as like ADC values (P value>0.05). It is due to rise in the RI value in renal dysfunction patient depends on pathology (tubulo interstitial / glomerular) . In this study we didn't selected patients with proven pathology .so it is unable to correlate the RI with the cause of pathology.

- Pearson correlation: There is Positive but weak correlation between RT RI and creatinine: 0.314 (p= 0.06), between LT RI and creatinine: 0.264 (p=0.06). This necessitates the further study for with known histopathological causes for renal dysfunction.

DISCUSSION

DISCUSSION

The Renal parenchyma of the patients with elevated renal parameters has shown significantly low level of ADC compare to those with normal renal serum markers. Similar kind of results observed in other studies also. [7,12-15]

Lower ADC values in renal parenchymal disease which causing rise in the serum creatinine, Blood Urea is probably due to reduced perfusion and reduced water diffusion.

The cause for reduction in the ADC level in Glomerulo-sclerosis, tubular atrophy, and interstitial fibrosis is due to reduction in free movement of water molecules both in the intra and extra-cellular space causing low ADC level.

Values of ADC lesser than 1.716 ($\times 10^{-3}$ mm^2/s) in RT side,1.704($x10^{-3}$ mm^2/sec) for left side were seen inpatients only with highly elevated Sr.creatinine(5mg/dl).

ADC greater than 2.494 ($\times 10^{-3}$ mm^2/s) for Right side, and2.468($x10^{-3} mm^2/s$) for left side were seen only in normal patients and not seen in renal dysfunction.

For a cut-off ADC value of 2.326 ($\times 10^{-3}$ mm^2/s), sensitivity was 83.6%, specificity was 84.7%, and 95% confidence intervals = (0.562, 0.878) for left side (values below cut-off indicated renal dysfunction).

Average ADC VALUE FOR BOTH SIDE: 2.334 $\times 10^{-3}$ mm^2/s.

Values of ADC below this cut off will indicate renal dysfunction.

ADC values and S.Creatinine/Blood urea level having a inverse association. Increase in the serum creatinine will decrease in the ADC value. Very low level of ADC will be seen only in patient with very much elevated creatinine level and stage 4, 5 CKD patients.

There is a positive linear correlation between renal parenchymal ADC values and Glomerular filtration Rate in renal failure patients. [12, 15] High ADC values will be seen in patient with normal GFR.

The mean ADC values of various groups of creatinine were differing significantly with each other. There is inverse relation between ADC value and serum creatinine and showed a decreasing trend with increasing level of creatinine and stage of CKD.

Low ADC values are statistically significant with increasing stage of chronic kidney disease. So the ADC values can be added additionally to asses and monitor the stage of renal dysfunction.

Similar to serum creatinine level, If the base line ADC values are fixed then will be helpful in monitoring of parenchymal disease progression.

Cut-offs can be established for ADC values for differentiation among various stages of CKD.

In this ADC Values of the asymmetric kidneys of two patients were differing with ADC value of above 2.42 $x10^{-3}mm^2/sec$ noted in the normal side (LT) and decreased ADC1.53 $x10^{-3}mm^2/sec$ was measured in the small sized kidney(RT).

(One Of the two patient is extra adrenal pheochromocytoma, lesion causing compression of RT renal artery and RT renal infarct which shows low ADC values on the right and showed parvustardus pattern on the Doppler examination.) So we can asses the ADC values of the individual kidneys by which we can asses the function of the each kidney separately.

ADC values in the cystic renal disease where high when measuring in the cysticareas. So patients with cysts in the kidneys measurement of ADC done at non cystic areas.

ADVANTAGES:

DW-MRI in monitoring of renal function has following advantages.

- Short acquisition time
- Non-invasive character
- Absence of ionizing radiation
- No contrast agents.
- NO subjective variation
- Each kidney can be separately examined
- Morphological and functional detail can be obtained together in a single study
- Other associated organ pathology can be detected.
- We can differentiate malignant and benign lesion in case of mass lesion

Drawbacks:

- Availability and cost.
- We should aware that Diffusion Weighted -MRI is in not alternate to serum markers (Blood Urea, Serum creatinine) or radio nucleotide study for evaluation of renal failure.
- It will serves as anextra tool, adding of which to the existing protocols will give more functional details.

Limitations of the study

- Sample size of study group was small.
- Patients with renal dysfunction without known aetiology.
- No Standardized protocol for the renal DW‐MRI.
- The major limitations for wide-spread use of DWI are regarding the selection of b values for renal imaging. Different studies done with different b values so fixing cut off values will be difficult.
- Detailed works needed in the evaluation of the precision and accuracy of the ADC values obtained with different MRI systems. Final results will allow investigators to reliably fix ADC Values and confidently apply DWI in clinical practice.

CONCLUSIONS

CONCLUSION

- Apparent Diffusion Co-efficient value can be implemented as an additional Marker to identify level of the renal function.
- ADC will be helpful in identifying the stage of renal dysfunction.
- ADC will be useful especially in patients those who undergoing MRI examination for other reasons we use the ADC value to detect renal dysfunction.
- It will be helpful known CKD patients to monitor the progression of disease.
- Assessment of kidney function by Diffusion Weighted Imaging will help to take the decision regarding contrast injection in patients who doesn't have renal disease previously when patient coming for MRI examination.
- ADC values can measure each kidney separately and values are individually correlating with the elevated renal parameters. So we can asses the single kidney function separately and the kidney which is most severely deranged can be identified separately.

- Cut-off values of ADC can be fixed for identifying renal impairment and also to find out the different stages of CKD.

- The functional and morphological details of renal parenchyma (collecting system-MRI urography, and renal vessels -MRI angiography, DWI- parenchymal diffusion) - will make the MRI as a onestop modality for complete renal evaluation.

- Renal resistive index has weak positive correlation with the elevated renal serum markers because rise in the RI depends on the pathology (either tubulo-interstitial/ glomerular), hence RI cannot be a reliable marker for identifying the stage of renal disease and to identify the progression of the renal dysfunction.

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ABBREVIATIONS

KEY WORDS:

ADC	:	Apparent diffusion co efficient value
ARF	:	Acute renal failure
AoCRF	:	Acute on chronic kidney disease
CKD	:	Chronic kidney disease
DWI	:	Diffusion weighted imaging
GFR	:	Glomerular filtration rate
MRI	:	Magnetic resonance imaging
RI	:	Resistive index
PSV	:	Peak systolic velocity
EDV	:	End diastolic velocity

PROFORMA

Name :

Age and sex :

Weight :

IP/ OP number :

Ward number :

Address :

HISTORY:

PAST HISTORY:

INVESTIGATION:

1.Serumcreatinine

2.Blood urea

3.Renal Doppler examination RI Right: ☐ RI left: ☐

4.Diffusion weighted imaging of kidneys ADC Right: ☐

ADC Left : ☐

5.eGFR

Interpretation:

PATIENT CONSENT FORM

TO STUDY THE RELATIONSHIP OF APPARENT DIFFUSION COEFFICIENT (ADC) VALUES OF RENAL PARENCHYMA AND RENAL RESISTIVE INDEX(RRI) WITH SERUM MARKERS OF RENAL DYSFUNCTION AND STAGE OF CHRONIC KIDNEY DISEASE

Institution : **Barnard Institute of Radio Diagnosis,**
Madras Medical College,
Chennai-600 003.

Name : Date :

Age : IP No :

Sex : Project Patient No :

The details of the study have been provided to me in writing and explained to me in my own language.

I confirm that I have understood the above study and had the opportunity to ask questions.

I understood that my participation in the study is voluntary and that I am free to withdraw at any time, without giving any reason, without the medical care that will normally be provided by the hospital being affected.

I agree not to restrict the use of any data or results that arise from this study provided such a use is only for scientific purpose(s).

I have been given an information sheet giving details of the study.

I fully consent to participate in the above study

_____	_____	_____
Name of the Subject	**Signature**	**Date**

ஆராய்ச்சி தகவல் தாள்

எம்.ஆர்.ஐ (MRI) மற்றும் டாப்ளர் (DOPPLER) ஸ்கேன் மூலம் சிறுநீரகம் பழுதடைந்தவர்களுக்கு (RENAL DYSFUNCTION) சிறுநீரகங்களின் செயலிழந்த நிலையினை கண்டறிவதற்கான ஆய்வு

சென்னை அரசு பொது மருத்துவமனையிக்கு வரும் நோயாளிகளில் எம்.ஆர்.ஐ (MRI) மற்றும் டாப்ளர் (DOPPLER) ஸ்கேன் மூலம் சிறுநீரகம் பழுதடைந்தவர்களுக்கு (RENAL DYSFUNCTION) சிறுநீரகங்களின் செயலிழந்த நிலையினை கண்டறிவதற்கான ஆராய்ச்சி.

முடிவுகளை அல்லது கருத்துக்களை வெளியிடும்போதோ அல்லது ஆராய்ச்சியின்போதோ தங்களது பெயரையோ அல்லது அடையாளங்களையோ வெளியிட மாட்டோம் என்பதை தெரிவித்துக்கொள்கிறோம்.

இந்த ஆராய்ச்சியில் பங்கேற்பது தங்களுடைய விருப்பத்தின்பேரில்தான் இருக்கிறது. மேலும் நீங்கள் எந்த நேரமும் இந்த ஆராய்ச்சியிலிருந்து பின்வாங்கலாம் என்பதையும் தெரிவித்துக்கொள்கிறோம்.

இந்த சிறப்பு பரிசோதனைகளின் முடிவுகளையும் நோயின் தன்மை பற்றியும் ஆராய்ச்சியின்போது அல்லது ஆராய்ச்சியின் முடிவின்போது தங்களுக்கு அறிவிப்போம் என்பதையும் தெரிவித்துக்கொள்கிறோம்.

ஆராய்ச்சியாளர் கையொப்பம் **பங்கேற்பாளர் கையொப்பம்**

நாள் :
இடம் :

ஆராய்ச்சி ஒப்புதல் கடிதம்

எம்.ஆர்.ஐ (MRI) மற்றும் டாப்ளர் (DOPPLER) ஸ்கேன் மூலம் சிறுநீரகம் பழுதடைந்தவர்களுக்கு (RENAL DYSFUNCTION) சிறுநீரகங்களின் செயலிழந்த நிலையினை கண்டறிவதற்கான ஆய்வு

பெயர்	:	தேதி	:
வயது	:	உள் நோயாளி எண்	:
பால்	:	ஆராய்ச்சி சேர்க்கை எண்	:

இந்த ஆராய்ச்சின் விவரங்களும் அதன் நோக்கங்களும் முழுமையாக எனக்கு தெளிவாக விளக்கப்பட்டது.

எனக்கு விளக்கப்பட்ட விஷயங்களை நான் புரிந்துகொண்டு எனது சம்மதத்தை தெரிவிக்கிறேன்.

இந்த ஆராய்ச்சியில் பிறரின் நிர்பந்தமின்றி என் சொந்த விருப்பத்தின்பேரில் பங்கு பெறுகின்றேன். இந்த ஆராய்ச்சியில் இருந்து நான் எந்நேரமும் பின்வாங்கலாம் என்பதையும் அதனால் எந்த பாதிப்பும் ஏற்படாது என்பதையும் நான் புரிந்துகொண்டேன்.

இந்த ஆராய்ச்சியின் விபரங்களைக் கொண்ட ஆராய்ச்சித் தகவல் தாளைப் பெற்றுக் கொண்டேன்.

நான் என்னுடைய சுய நினைவுடனும் மற்றும் முழு சுதந்திரத்துடனும் இந்த மருத்துவ ஆராய்ச்சியில் என்னை சேர்த்துக்கொள்ள சம்மதம் தெரிவிக்கிறேன்.

கையொப்பம்

MASTER CHART

S. No	Name	Age	Sex	Urea	Creatinine	ADCx10-3mm2/sec		RI		GFR
						Rt	Lt	Rt	Lt	
1	Palani	40	M	31	0.7	2.362	2.451	0.61	0.6	92.6
2	Shanthi	39	M	38	1	2.403	2.362	0.62	0.62	90.1
3	Kalaivani	34	F	41	1.5	2.562	2.432	0.61	0.6	70.9
4	Vidya	21	F	35	0.9	2.584	2.609	0.62	0.62	93
5	Yasmin	25	F	38	1	2682	2.701	0.6	0.6	81.5
6	Joseph David	42	M	29	1	2.362	2.343	0.62	0.59	92
7	Karuppan	40	M	30	1.1	2.344	2.4	0.62	0.62	90
8	Kavya	34	F	39	1	2.482	2.422	0.59	0.54	77.5
9	Dinesh	41	M	40	1	2.488	2.422	0.62	0.62	91.1
10	Malini	24	F	36	0.9	2.564	2.462	0.6	o.60	107
11	Geetha	36	F	33	0.9	2.522	2.403	0.59	0.59	75
12	Sharmila	39	F	30	0.8	2.386	2.465	0.59	0.54	81
13	John Priya	19	F	29	0.7	2.524	2.393	0.62	0.6	93.6
14	Senthil	22	M	36	0.82	2.624	2.703	0.62	0.58	107
15	Murugan	55	M	42	1.2	2.262	2.243	0.66	0.62	64.7
16	Kannamal	50	F	46	1.5	2.172	2.183	0.65	0.66	70.9
17	Rajesh	35	M	44	1.3	2.262	2.201	0.62	0.63	85.1
18	Kumar	45	M	42	0.9	2.464	2.334	0.62	0.62	79.2
19	Deenadhayal	45	M	50	1.6	2.233	2.28	0.64	0.64	78.2
20	Angel	21	F	36	0.9	2.642	2.62	0.62	0.55	120
21	Janath Fathima	24	F	38	0.8	2.561	2.56	0.6	0.61	77.1
22	Lawanya	26	F	42	0.9	3.28	3.26	0.58	0.58	83.6
23	Nagarani	28	F	42	1.5	2.672	2.68	0.67	0.63	98.9
24	Manjula	39	F	42	0.9	2.334	2.447	0.62	0.64	98.8

S. No	Name	Age	Sex	Urea	Creatinine	ADCx10-3mm2/sec		RI		GFR
						Rt	Lt	Rt	Lt	
25	Krishnamoorthi	41	M	32	0.9	2.57	2.62	0.58	0.62	79.4
26	Prakash	14	M	40	0.8	2.56	2.569	0.6	0.7	95
27	Kuppan	48	M	42	0.96	2.562	2.48	0.62	0.67	96.6
28	Suganya	46	F	36	0.8	2.6	2.509	0.62	0.62	101
29	Kumaran	36	M	41	0.9	2.432	2.45	0.61	0.63	94.2
30	Sethu	52	M	42	1	2.356	2.42	0.59	0.58	81
31	Kumari	25	F	45	0.9	2.546	2.562	0.6	0.59	75.3
32	Unnamalaia	36	F	42	0.8	2.62	2.622	0.59	0.62	97
33	Balaji	45	M	44	0.7	2.611	2.52	0.61	0.65	114
34	Rajendran	45	M	44	0.8	2.428	2.622	0.62	0.63	103
35	Kaveri	32	F	40	0.9	2.262	2.46	0.69	0.64	96.6
36	Soundarya	46	F	36	1	2.622	2.402	0.6	0.63	114.9
37	Rani	26	M	37	0.7	2.52	2.402	0.62	0.62	83
38	Samundi	29	M	30	0.9	2.342	2.428	0.62	0.61	111.2
39	Suresh	24	M	32	1	2.562	2.561	0.6	0.67	85.9
40	Naveen	17	M	38	0.8	2.403	2.46	0.59	0.6	85.8
41	Balaraman	45	M	39	1.5	2.344	2.36	0.58	0.62	100.8
42	Nareshkumar	26	M	39	1.1	2.426	2.562	0.59	0.64	95.6
43	Lekha	29	F	40	1	2.365	2.021	0.61	0.67	65.4
44	Saravanan	64	M	42	1	2.382	2.36	0.62	0.61	90.2
45	Sasikala	38	F	42	1.1	2.682	2.592	0.6	0.63	90
46	Geetha	30	F	32	0.9	2.632	2.531	0.6	0.63	84.6
47	Kabali	50	M	36	0.8	2.63	2.31	0.59	0.59	136
48	Saravanan	24	M	35	0.9	2.53	2.462	0.59	0.58	121.7
49	Thenmozhi	24	F	32	0.85	2.432	2.31	0.61	0.62	94.3
50	Dinesh	22	M	36	1	2.453	2.344	0.62	0.62	96

MASTER CHART

S. No	Name	Age	Sex	Urea	Creatinine	ADC:Ax10-3 mm2/sec		FI		GFR
						Rt	Lt	Rt	Lt	
1	Dinesh	28	M	117.2	7.2	1.904	1.807	0.71	0.69	12.1
2	Nilmu	19	M	152	8.4	1.886	1.903	0.68	0.71	11.8
3	Dhandabani	48	M	142	7.2	1146	1.703	0.71	0.76	11
4	Manohar	42	M	140	62	1.77	1.56	0.72	0.74	12.3
5	**Manikandan**	19	M	48	1.7	1.53	2.42	0.62	0.76	61.3
6	Srinivasan	48	M	49	1.7	2	2.3	0.71	0.65	48.9
7	Arumugam	48	M	112	7.6	2.2	2.1	0.72	0.72	9.1
8	**Karuppan**	52	F	51	1.6	2.07	2.4	0.69	0.65	44.2
9	Suresh	45	M	52	1.9	1.95	2.07	0.68	0.7	43.1
10	Srinivasan	47	M	48	1.6	2310	2.37	0.62	0.66	54.1
11	Kaviya	33	F	45	1.7	2.2	2.16	0.6	0.6	48.9
12	Sunitha	38	F	54	1.9	2.408	2.4	0.67	0.6	45.2
13	Saritha	34	F	77	3.5	1.91	1.96	0.68	0.69	37.1
14	Kuppusamy	62	M	155	12	1.37	1.31	0.7	0.7	20.4
15	Krishnamoorthy	41	M	77	2.2	2.12	1.9	0.68	0.6	7.6
16	Prakash	49	M	78	3.5	1.73	1.66	0.7	0.7	36.9
17	Jhonson	55	M	56	1.8	2.1	2.098	0.62	0.61	20.9
18	Nagarani	52	F	58	1.7	1.912	2.171	0.6	0.59	39.4
19	Raman	60	M	48	2.1	2.21	2.17	0.62	0.62	33.9
20	Devahi	50	F	52	1.9	2.12	2.231	0.65	0.65	38.8
21	Arundoss	53	M	60	2.3	2.168	1.926	0.62	0.68	35.7
22	Parthasarathy	58	M	130	12.1	1.526	1.526	0.74	0.72	36
23	Padmavathy	46	F	128	14.1	1.463	1.4	0.68	0.54	27.5
24	Sekar	40	M	120	8.6	1.58	1.56	0.58	0.62	7.9

S. No	Name	Age	Sex	Urea	Creatinine	ADC:Ax10-3 mm2/sec		FI		GFR
						Rt	Lt	Rt	Lt	
25	Balaji	48	M	112	9.5	1.7	1.621	0.71	0.73	7
26	Govindaraj	67	M	156	8	1.628	1.58	0.69	0.72	7
27	Kaliyappan	66	M	131	6.5	1.62	1.452	0.69	0.7	6.4
28	Balu	28	M	98	7	1.312	1.55	0.71	0.7	10.5
29	Janakiraman	38	M	88	3.5	2.781	2.802	0.68	0.67	10.2
30	Shanthi	29	F	70	4.8	1.802	1.628	0.72	0.7	12.1
31	Jayaraman	58	M	72	5	1.621	1.621	0.69	0.79	18.9
32	Elumalai	43	M	62	2.1	1.912	2.12	0.59	0.58	17.4
33	Rangan	48	M	60	2.4	2.012	2.1	0.62	0.62	13.2
34	Gopal	56	M	47	1.8	2.201	2.12	0.58	0.6	37.8
35	Srichev	62	M	4.85	2	2.12	2.2	0.68	0.65	30.7
36	Renumuel	60	F	70	3.5	1.821	1.799	0.7	0.68	36.7
37	Perumal	60	M	82	4.2	1.788	1.8	0.72	0.71	32.8
38	Raji	48	M	68	5.6	1.912	2.314	0.62	0.69	24.8
39	Agila	46	F	64	4.9	1.782	1.812	0.59	0.62	15.9
40	Shankar	60	M	62	6.02	1.6	1.702	0.72	0.7	10.7
41	Megala	62	M	58	4.2	1.912	1.728	0.7	0.7	13.9
42	Selvi	56	F	81	3.9	1.812	1.8	0.71	0.72	7.9
43	Mariappan	46	M	60	3.1	2.1	1.912	0.69	0.71	19.4
44	Shanthi	48	F	130	6.2	1.682	1.7	0.7	0.7	25.6
45	Saroja	52	F	54	1.9	2.172	2.019	0.61	0.62	33
46	Mahalakshmi	46	F	58	2.1	2.001	2.16	0.65	0.67	30.4
47	Geetha	52	F	52	1.9	2.11	2.174	0.58	0.59	24.7
48	Ganapathy	46	M	56	1.7	2.206	2.125	0.62	0.68	41.2
49	Mannan	48	M	40	1.8	2.201	2.156	0.7	0.62	51.1
50	Rajeshwar	42	M	55	2	2.162	2.21	0.58	0.72	49

INSTITUTIONAL ETHICS COMMITTEE
MADRAS MEDICAL COLLEGE, CHENNAI-3

EC Reg No.ECR/270/Inst./TN/2013
Telephone No. 044 25305301
Fax : 044 25363970

CERTIFICATE OF APPROVAL

To
Dr.K.Sivakumar
Post Graduate in MD.Radiodiagnosis,
Barnard Institute of Radiology
Madras Medical College,
Chennai – 600 003.

Dr.K.Sivakumar,

The Institutional Ethics Committee has considered your request and approved your study titled **"TO STUDY THE RELATIONSHIP OF APPARENT DIFFUSION COEFFICIENT (ADC) VALUES OF RENAL PARENCHYMA AND RENAL RESISTIVE INDEX (RRI) WITH SERUM MARKERS OF RENAL DYSFUNCTION AND STAGE OF CHRONIC KIDNEY DISEASE. " No. 06072014.**

The following members of Ethics Committee were present in the meeting held on 01.07.2014 conducted at Madras Medical College, Chennai-3.

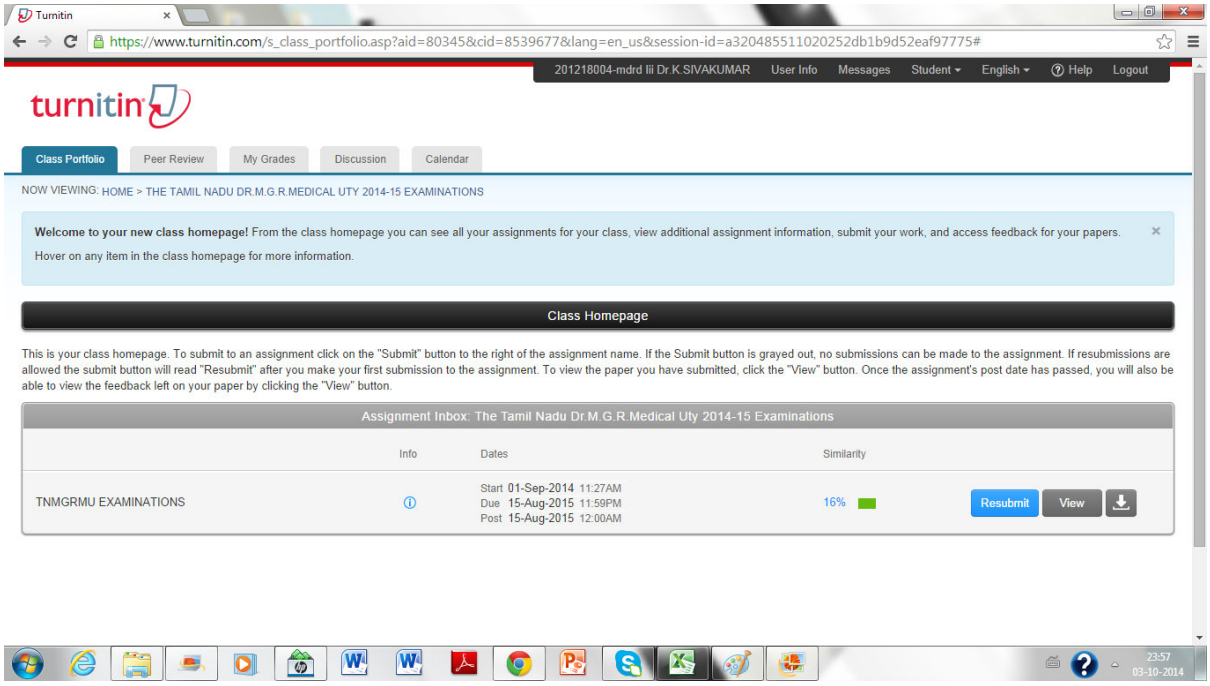
1.	Dr.C.Rajendran, M.D.,	: Chairperson
2.	Dr.R.Vimala, M.D., Dean, MMC, Ch-3	: Deputy Chairperson
3.	Prof.B.Kalaiselvi, M.D., Vice-Principal, MMC, Ch-3	: Member Secretary
4.	Prof.R.Nandhini, M.D., Inst.of Pharmacology, MMC	: Member
5.	Dr.G.Muralidharan, Director Incharge, Inst.of Surgery	: Member
6.	Prof.Md.Ali, M.D., D.M., Prof & HOD of MGE, MMC	: Member
7.	Prof.K.Ramadevi, Director i/c, Inst.of Biochemistry, MMC	: Member
8.	Prof.Saraswathy, M.D., Director, Pathology, MMC, Ch-3	: Member
9.	Prof.Tito, M.D., Director i/c, Inst.of Internal Medicine, MMC	: Member
10.	Thiru S.Rameshkumar, Administrative Officer	: Lay Person
11.	Thiru S.Govindasamy, B.A., B.L.,	: Lawyer
12.	Tmt.Arnold Saulina, M.A., MSW.,	: Social Scientist

We approve the proposal to be conducted in its presented form.

The Institutional Ethics Committee expects to be informed about the progress of the study and SAE occurring in the course of the study, any changes in the protocol and patients information/informed consent and asks to be provided a copy of the final report.

Member Secretary, Ethics Committee

MEMBER SECRETARY
INSTITUTIONAL ETHICS COMMITTEE
MADRAS MEDICAL COLLEGE
CHENNAI-600 003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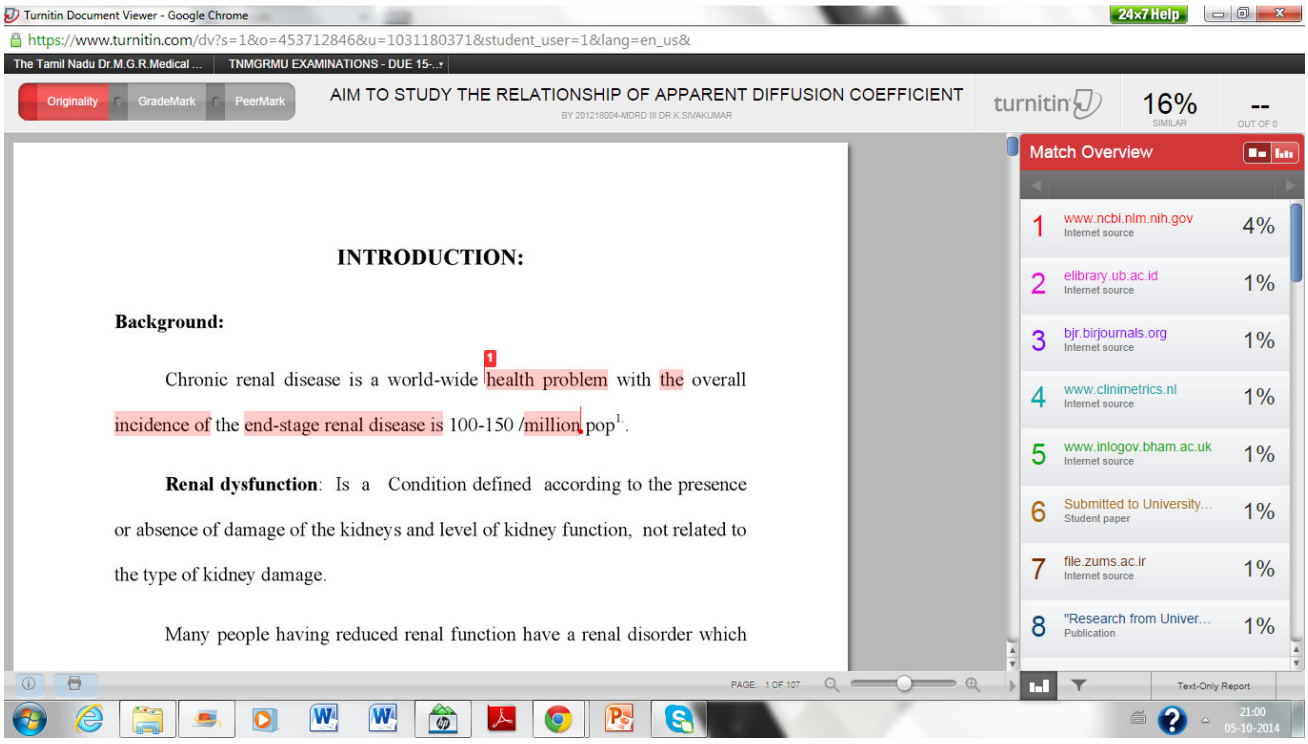
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INTRODUCTION:
Background:
Chronic renal disease is a world-wide health problem with the overall incidence of the end-stage renal disease is 100-150 /million pop[1].
Renal dysfunction: Is a Condition defined according to the presence or absence of damage of the kidneys and level of kidney function, not related to the type of kidney damage.
Many people having reduced renal function have a renal disorder which
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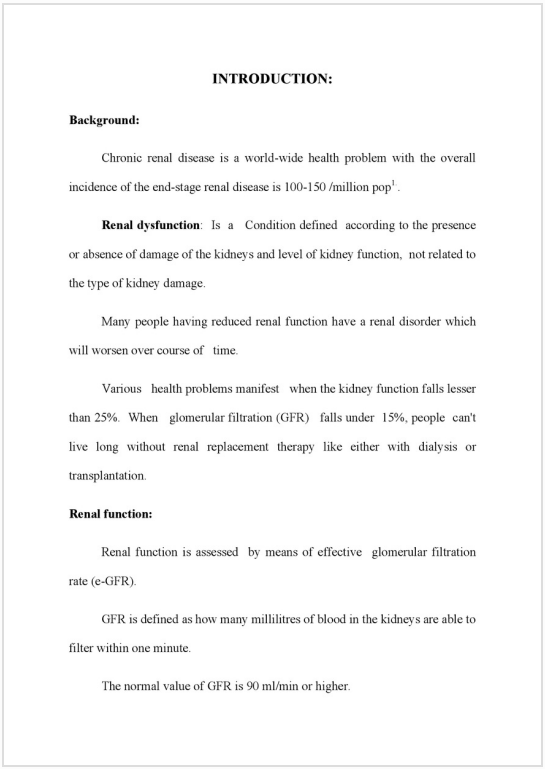

INTRODUCTION:

Background:

Chronic renal disease is a world-wide health problem with the overall incidence of the end-stage renal disease is 100-150 /million pop[1].

Renal dysfunction: Is a Condition defined according to the presence or absence of damage of the kidneys and level of kidney function, not related to the type of kidney damage.

Many people having reduced renal function have a renal disorder which will worsen over course of time.

Various health problems manifest when the kidney function falls lesser than 25%. When glomerular filtration (GFR) falls under 15%, people can't live long without renal replacement therapy like either with dialysis or transplantation.

Renal function:

Renal function is assessed by means of effective glomerular filtration rate (e-GFR).

GFR is defined as how many millilitres of blood in the kidneys are able to filter within one minute.

The normal value of GFR is 90 ml/min or higher.